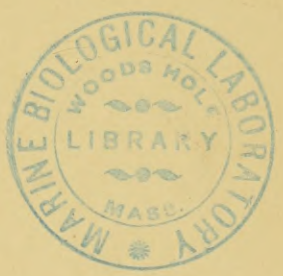
MEDDELELSER OM GRØNLAND



MEDDELELSER OM GRØNLAND

UDGIVNE AF

KOMMISSIONEN FOR
LEDELSEN AF DE GEOLOGISKE OG GEOGRAFISKE
UNDERSØGELSER I GRØNLAND

BIND XLVI

MED 7 TAVLER OG 105 FIGURBLADE

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1917

DANMARK-EKSPEDITIONEN

TIL GRØNLANDS NORDØSTKYST 1906—1908

UNDER LEDELSE AF

L. MYLIUS-ERICHSEN

BIND VI

INDHOLD

Side

Editorial Note.

I. Die glaciologischen Beobachtungen der Danmark-Expedition von I. P. Koch und A. Wegener. (Hertil Tavle I og 38 Figurblade.) 1

Inhalt 3

II. Survey of Northeast Greenland by I. P. Koch. (Hertil Tavle II—VII og 67 Figurblade.) 79

Contents 467

EDITORIAL NOTE

The committee which was appointed in 1906 for the "Danmark-Ekspeditionen til Grønlands Nordøstkyst 1906—08" consisted — in addition to the leader of the Expedition, M. Mylius-Erichsen — of Captain (now Commodore) G. Amdrup, Valdemar Glückstadt, consul-general, Erik S. Henius, consul, and Commodore G. Holm, and held its first meeting on March 28th, 1906. When the Expedition returned in the autumn of 1908, bringing home considerable scientific material, the committee was supplemented with Professor Hector Jungersen, Professor N. V. Ussing and Professor Eug. Warming to conduct the investigation and publication of this material. Professor Warming undertook the position of chairman of the committee.

Mylius-Erichsen perished during the Expedition; for further particulars see G. Amdrup: Report on the Danmark Expedition, vol. XLI, pp. 187—223.

Of the remaining seven members of the committee, Professor Ussing died on July 23rd, 1911 and Professor Jungersen on March 6th, 1917, a loss which is greatly to be deplored.

The funds for the investigation and publication of the material in question were very generously granted by the Rigsdag and by the Carlsberg Fund.

According to an agreement with the "Kommissionen for Ledelsen af de geologiske og geografiske Undersøgelser i Grønland", it was decided that the publications of the Expedition should be included in six consecutive volumes of "Meddelelser om Grønland", viz. vols. XLI—XLVI.

The committee, regarding its task as now completed, expresses its thanks to all who have in various ways assisted it in its work, and delivers over the completed work to the above named commission.

Komitéen for Danmark-Ekspeditionen
til Grønlands Nordøstkyst 1906—1908.

October 15th, 1917.

G. AMDRUP. VALD. GLÜCKSTADT. ERIK S. HENIUS.

G. HOLM. EUG. WARMING.

I.

DIE GLACIOLOGISCHEN BEOBACHTUNGEN DER DANMARK-EXPEDITION

VON

I. P. KOCH UND A. WEGENER

1911

INHALT

Seite

Einleitung 5

Kapitel I. Das schwimmende Inlandeis der Jökelbugt 7

II. Der Gletscher zwischen Lamberts-Land und Hovgaards-Ø 17

— III. Das Inlandeis auf dem Lande westlich der Station 20

1. Die Schlittenreise vom Sælsö zum Dronning-Louises-Land (Märzreise) 22

2. Die Schlittenreise vom Annekssö nach Ymers-Nunatak (Maireise) .. 30

3. Die „Morænelandskab" nordwestlich des Annekssö 43

— IV. Das Inlandeis von Kronprins-Christians-Land 49

— V. Lokale Gletscher und Firngebiete 52

— VI. Die Schneewehengletscher auf Germania-Land 56

— VII. Die Gnipa-Höhle 64

34267

EINLEITUNG

Das Gebiet, dessen Vergletscherung im folgenden beschrieben werden soll, ist hauptsächlich die nähere Umgebung der Winterstation der Danmark-Expedition, auf $76^3/_4°$ nördlicher Breite an der Ostküste Grönlands, erstreckt sich aber auch auf die nördlich und südlich davon gelegenen Küstenstriche, soweit diese bereist wurden, nämlich von etwa 75° bis $83^1/_2°$ Breite.

Während weiter im Süden, am Franz-Joseph-Fjord und Scoresby-Sund, ein ziemlich breites, vom Inlandeise freigelassenes Küstengebirge mit recht bedeutenden Erhebungen über dem Meere vorhanden ist, wird der eisfreie Küstenstreifen nach Norden immer niedriger und zugleich schmaler. Die Erhebungen in der Nähe der Winterstation liegen sämtlich unterhalb 1000 M, und das Inlandeis tritt bereits im Südwesten und Westen vom Danmarks-Havn (im Innern der Dove-Bugt) in Gestalt von zwei mächtigen Gletschern, dem Soranerbræ und dem Brede-Bræ (vergl. die Karte 1 : 500 000) auf das Meer hinaus. Nördlich vom Winterquartier wird das eisfreie Vorland noch schmaler, und in der Gegend von Lamberts-Land ist überhaupt kein zusammenhängender Streifen mehr vorhanden, sondern nur noch einzelne Landkomplexe, die durch breite Eisströme von einander getrennt sind. Weiter nördlich treffen wir freilich wieder ein zusammenhängendes eisfreies Gebiet zwischen etwa $79^1/_2°$ und $80^3/_4°$ Breite, gebildet durch ein fjordreiches höheres Küstengebirge, welches dem Inlandeise hier den Weg versperrt und gleichzeitig den an seinem Ostabhange gelegenen Sedimenten Schutz vor der Abrasion durch das Eis gewährt; aber noch höher im Norden, wo der Gebirgscharakter sich völlig verliert, verschwindet auch die Küstenlinie wieder fast ganz unter dem Eise.

Mit Hinblick auf die geringe Niederschlagsmenge muss man also die Eisbedeckung im Nordosten Grönlands als sehr stark bezeichnen. Im Gegensatz hierzu scheint das wieder stark gebirgige Peary-Land fast ganz frei von Inlandeis zu sein, soweit sich dies aus den Reisen von Peary und denen der Danmark-Expedition beurteilen lässt.

Diese starke Eisbedeckung nördlich vom Winterquartier der Danmark-Expedition hat hier, begünstigt durch lokale Faktoren, auf der Strecke zwischen 78° und 79½° Breite Verhältnisse geschaffen, wie sie bisher nur aus der Antarktis bekannt waren; denn das Inlandeis schiebt sich hier in zusammenhängender Masse über die Meeresoberfläche fort, ohne in Eisberge zu zerfallen. Diese Erscheinung wird im folgenden eingehender zu schildern sein. Im übrigen bot das auf dem Lande liegende Inlandeis westlich der Station Gelegenheit, die Erscheinungsformen der „Randzone" kennen zu lernen, die hier in sehr prägnanter Weise ausgebildet ist.

Natürlich ist auch das gegenwärtig vom Inlandeise verschonte Küstengebiet nicht ganz frei von Vergletscherung. Es finden sich hier noch eine Reihe von meist kleinen Lokalgletschern und selbständigen Firngebilden, die nicht in Zusammenhang mit dem Inlandeise stehen. Eine besonders typische Erscheinungsform stellen die Schneewehengletscher dar, welche in der näheren Umgebung der Winterstation, auf Germania-Land, in grosser Zahl gefunden wurden; sie geben Anlass zur Ausbildung von interessanten Eishöhlen, von denen namentlich eine, die Gnipa-Höhle, im folgenden eingehend beschrieben werden soll.

KAPITEL I.

Das schwimmende Inlandeis der Jökelbugt.

Die jüngsten Südpolarexpeditionen haben an verschiedenen Stellen der Antarktis schwimmendes Inlandeis gefunden, das in wechselnden Erscheinungsformen zur Beobachtung gelangte, und dessen Entstehungsbedingungen auch von den Beobachtern in verschiedener Weise aufgefasst worden sind. Das Barriere-Eis bei Victoria-Land ist nach Scotts Beschreibung[1]) eine gewaltige schwimmende Tafel aus Inlandeis, welche sich auf der Oberfläche des Wassers mit einer Geschwindigkeit von 1/2 Km jährlich fortschiebt. An der Ostseite der „Westantarktis" hat Nordenskiöld eine Eismasse gefunden, die dem Barriere-Eis sehr ähnlich ist, von welcher Nordenskiöld aber glaubt, sie habe sich auf dem Meere durch Niederschlag gebildet[2]). v. Drygalski fand am Gaussberg gleichfalls schwimmendes Inlandeis, nämlich das sog. „Westeis", welches er für einen absterbenden, völlig bewegungslosen Rest des Inlandeises hält[3]). Aus nordpolaren Gebieten waren ähnliche Erscheinungen bisher nicht beobachtet worden, und dies dürfte dem folgenden Bericht noch ein erhöhtes Interesse verleihen.

Fast die ganze zwischen 78° und 79° Breite gelegene Jökelbugt (vergl. die Karte 1 : 1000000, südliches Blatt) ist mit einer zusammenhängenden Inlandeismasse bedeckt, die zum grossen Teil auf dem Wasser schwimmt. Das Eis strömt südlich von Lamberts-Land in einem etwa 40 Km breiten Gletscher auf die Bucht hinaus und stösst hier gegen die quer vorgelagerte Schnauder-Ø. Ein kleinerer Teil wendet sich von hier nach Norden und endet kurz vor der östlichsten

[1]) R. F. Scott, The Voyage of the Discovery, London 1905.

[2]) O. Nordenskiöld, „Antarktis", zwei Jahre in Schnee und Eis am Südpol. Berlin 1904.

[3]) E. v. Drygalski, Zum Continent des eisigen Südens, Berlin 1904, und: Das Schelfeis der Antarktis am Gaussberg, Sitz. Ber. d. K. B. Ak. d. Wiss. 1910, No. 9, sowie Zeitschrift f. Gletscherkunde I, S. 62, — Siehe auch die Zusammenstellung von E. Philippi: Über die Landeisbeobachtungen der letzten fünf Südpolarexpeditionen, = Zeitschr. f. Gletscherkunde II, S. 1, 1907, und v. Drygalski: Die Vereisung von Meeresräumen, ihre Möglichkeiten, Entwicklung und Wirkung, = Verhdlg. d. Schweiz. Naturforsch. Ges., 93. Jahresvers., 4.—7. Sept. 1910, Basel 1910.

Spitze von Lamberts-Land, etwa 5 Km südlich von Brönlunds-Grav. Die Hauptmasse aber nimmt den breiteren und offeneren Weg nach Süden in der Richtung auf die Pariseröer, wo ein Teil in der Lücke östlich des sogen. „Nordre-Depots“ sogar noch weiter nach Süden dringt und beinahe die Südküste der Jökelbugt erreicht. Nur der Südwestwinkel dieser Bucht ist frei vom Inlandeise; einige der Gletscher, welche hier zum Meere hinabsteigen, kalben, und man trifft hier Eisberge und Kalbeisstücke, welche offenbar meist an Ort und Stelle abschmelzen, und nur sehr selten hinausgelangen können.

Diese Jökelbugt ist auf der Danmark-Expedition 9 mal mit Schlitten vollständig passiert worden, und zwar jedesmal auf einer neuen Route, so dass die Eisverhältnisse hier nach den Umständen sehr gut bekannt geworden sind. Schon im Herbst 1906, bei der Auslegung des „Nordre Depots“ fuhr man auf der Strecke zwischen Hagens-Ø und der Depot-Insel über die südlichste Zunge dieses Inlandeises. Dies Eis war zwar dicker als das Meereis, und oberflächlich gewellt, aber man erkannte damals noch nicht die Natur desselben; denn diese äusserste Zunge ist so ausgeflacht, dass man nicht leicht auf den Gedanken kommt, es mit Inlandeis zu tun zu haben. Auch bei der im Frühjahr 1907 folgenden Hauptschlittenreise erkannte man die wahre Natur des Eises erst, als man bei der Weiterreise vom Nordre-Depot aus nach Norden einen sehr erheblichen Anstieg auf dem Eise zu überwinden hatte. Bei der Rückreise, als der alles deckende Neuschnee bereits stark zusammengeschmolzen war, konnte man sehen, dass das Inlandeis sich im Norden von dieser Insel nach Osten zu vorbeischiebt, wobei eine Seitenmoräne etwa 500 M weit mitgeschleppt wird, dass es aber sogleich nach dem Freiwerden von der Insel nach rechts umbiegt und sich nach Süden wendet, hier die erwähnte, nach Süden immer flacher werdende Zunge bildend.

Fig. 1. Schraubung am Rande des schwimmenden Inlandeises am Nordre-Depot. Im Hintergrunde die Seitenmoräne. Jökelbugten, Mai 1907; Wegener phot.

Auf der weiteren Reise nach Norden über dieses Eis kamen wir bald an grosse Spalten, deren Beschaffenheit auch die letzten Zweifel heben musste. Einer solcher Spalte folgten wir etwa 50 Km weit,

Fig. 2. Zeltlager auf dem schwimmenden Inlandeise. Spalte im Vordergrund. Im Hintergrunde Land. Jökelbugten, April 1907; Wegener phot.

ihre wahre Länge dürfte aber erheblich grösser gewesen sein; ihre Tiefe war ziemlich konstant und betrug nach einer primitiven, mit Hülfe der ca. 6 M langen Hundepeitsche ausgeführten Schätzung etwa 25 M. An manchen Stellen löste sie sich in ein System kleinerer Spalten auf, welche sich weiterhin wieder zu einer grösseren vereinigten. An den Spaltenwänden konnte man eine deutliche horizontale Schichtung erkennen. Die Richtung dieser Spalte war SSW—NNE. Im Herbst 1907 wurde nördlich des Nordre-Depots eine andere, nach ENE gerichtete Spalte von noch grösseren Dimensionen gefunden, deren Tiefe auf 35 M, und deren Breite auf 200 M geschätzt wurde. Eine dritte sehr lange Spalte wurde bei der Rückreise von der Hauptschlittenexpedition im Frühjahr 1907 etwa 12 Km südlich von Brönlunds-Grav gefunden. Sie hatte die Richtung WSW—ENE. Der Boden aller dieser Spalten war eben und meist mit Schnee bedeckt; einmal konnten wir jedoch im Grunde schwach salziges Wasser konstatieren. Der Boden wird also offenbar durch die Meeresoberfläche gebildet. Ausser den genannten Spalten wurden aber noch zahlreiche andere getroffen. Offenbar ist die ganze Eistafel der Jökelbugt stark mit Spalten durchsetzt, die zwar im Frühjahr zum grossen Teil mit Schnee ausgefüllt, aber z. B. im Herbst 1907 bei der Entsatz-Schlittenreise für Mylius-Erichsen dem Fortkommen ausserordentlich hinderlich waren. Die Richtung ist überall sehr variierend, wenngleich die beiden Richtungen: mit der Eisbewegung und senkrecht dazu (Längs- und Querspalten) wenigstens bei den grössten Spalten bevorzugt zu sein scheinen.

Fig. 3. Spalte im schwimmenden Inlandeis. Jökelbugten, April 1907; Wegener phot.

Es kann nach unseren Beobachtungen nicht daran gezweifelt werden, dass wenigstens ein grosser Teil dieses Eises der Jökelbugt frei auf dem Wasser schwimmt, ohne den Grund zu berühren. Aller-

dings lässt sich das Gesamt-Areal des schwimmenden Eises gegen das dem Grunde aufsitzende nicht schärfer abgrenzen; dazu reichen die Beobachtungen bei dem offenbar häufigen Wechsel dieser Verhältnisse nicht aus. Dagegen lässt sich an einzelnen Punkten mit Sicherheit angeben, dass das Eis auf dem Boden steht, während an anderen Punkten ebenso sicher angenommen werden muss, dass es schwimmt. Das erstere ist z. B. der Fall unmittelbar an der Westküste der Jökelbugt, da hier bei einem Übergang auf das Land keine nennenswerte Gezeitenschraubung[1]) gefunden wurde, und es deuten manche Anzeichen darauf hin, dass dieser ganze westlichste Teil noch dem freilich unter Wasser gelegenen Boden aufruht. Im Gegensatz hierzu

Fig. 4. Schraubwall im schwimmenden Inlandeise. Jökelbugten, Juni 1907; Koch phot.

wurde längs der Südküste von Lamberts-Land eine starke Gezeitenschraubung gefunden, welche beweist, dass das Inlandeis hier mit den Gezeiten gehoben und gesenkt wird. Nicht allzu weit hiervon liegt aber der später zu besprechende Eisbuckel, bei dem das Eis also wiederum fest auf einer Klippe aufsitzt. Am Nordre-Depot scheint

[1]) Zur Erläuterung der Gezeitenschraubung möge die beifolgende Abbildung 5 dienen.

Die Gezeitenspalte und die Schraubung wird dadurch erzeugt, dass der mit dem Lande unmittelbar in Berührung stehende Teil der Meereises fest auf dem Grunde steht, während dasselbe in grösserer Entfernung vom Lande schwimmt. Die Gezeiten heben und senken die schwimmende Eisdecke, während der „Eisfuss“ längs der Küste festliegt; infolgedessen bildet sich die „Gezeitenspalte“ aus.

Das Gefrieren des Wassers in dieser Spalte in Verbindung mit den unvermeidlichen horizontalen Verschiebungen der schwimmenden Eisdecke erzeugt wiederum die „Gezeitenschraubung“.

Auf diese Weise bilden Eisfuss, Gezeitenspalte und Gezeitenschraubung ein nicht misszuverstehendes Kennzeichen für den Übergang zwischen dem schwimmenden und dem auf dem Grunde festsitzenden Eis.

Fig. 5. Eisfuss, Gezeitenspalte und Gezeitenschraubung des Meereises. März 1907; Wegener phot.

das Inlandeis gleichfalls zu schwimmen, da sich hier zwischen Meereis und Inlandeis keine Gezeitenschraubung findet. Dagegen wurde am Westrande der von hier nach Süden gehenden Zunge beim Übertritt auf das Meereis eine solche Gezeitenschraubung konstatiert, hier muss das Inlandeis also wieder dem Boden aufliegen. Diese Verhältnisse wechseln offenbar sehr häufig, und darauf dürfte auch wohl der grosse Spaltenreichtum zurückzuführen sein.

Den äusseren Rand dieser Inlandeismasse haben wir nur im Norden bei Lamberts-Land und im Süden in Gestalt der schon erwähnten sich ausflachenden Zunge nördlich von Hagens-Ø kennen gelernt. Auch bei Lamberts-Land flacht sich das Eis allmählich aus, ohne zu kalben, und man muss sehr Acht geben, wenn man unterwegs nicht die Grenze zwischen Meereis und Inlandeis verpassen will; auf der Rückreise von Brönlunds-Grav nach Süden fuhr man zuerst auf Meereis, nach 4 Km aber kam man an eine sehr unbedeutende Spalte, wie man schon früher mehrere passiert hatte; auf der anderen Seite dieser Spalte stieg das Eis aber allmählig an, und gleichzeitig zeigten sich die für Inlandeis charakteristischen Schmelzknollen und vertikalen Löcher im Eise; nach weiteren 8 Km kam man an die bereits früher erwähnte grosse Spalte, welche alle Zweifel an der Natur dieses Eises beseitigte.

Von besonderem Interesse ist die Frage, wie dieses teilweise schwimmende Inlandeis der Jökelbugt nach Osten zu begrenzt ist. Während westlich der Schnauder-Ø, zwischen dieser und den Pariseröer, und in den Sunden zwischen den letzteren überall Inlandeis gefunden wurde, traf man Meereis an der Ostküste der Schnauder-Ø, am Ostrande der südlicheren Inseln und in den südlicher gelegenen Sunden gegenüber den Björneskær und Hagens-Ø. Ebenso zeigte Bistrups Rückreise im Frühjahr 1907, dass westlich der geraden Verbindungslinie zwischen Ile-de-France und Norske-Ø eine ganz ebene, im Sommer anscheinend nicht aufbrechende Meereisdecke lag. Hieraus muss mit Notwendigkeit geschlossen werden, dass das Inlandeis auf seiner ganzen östlichen Front überall wie an den beiden von uns untersuchten Stellen in flachen Zungen endigt und nirgends kalbt. Hiermit steht auch durchaus in Übereinstimmung, dass keine der auf dem vorgelagerten Meereise reisenden Schlittenpartien Kalbeis oder Eisberge gesehen hat.

Es unterliegt keinem Zweifel, dass diese ganze Eismasse auf der Meeresoberfläche noch eine fortschreitende Bewegung bezitzt. Dies bezeugt z. B. die oben erwähnte Moräne, die vom Nordre-Depot nach Osten hinausgetragen wird. Noch auf der südlichsten Zunge des Inlandeises, zwischen Hagens-Ø und dem Nordre-Depot, wurden einzelne Lehmklösse im Eise gefunden, „im ganzen nur einige wenige

Kubikmeter", welche möglicherweise die Fortsetzung der genannten Moräne bilden. Auf eine solche fortschreitende Bewegung deuten auch die gewaltigen Zerklüftungen hin, die sich an solchen Stellen befinden, wo sich die Bewegungsrichtung des Eises stark ändert, wie z. B. am Südende der Schnauder-Ø (Fig. 6), oder östlich des Nordre-Depots. Wir hörten an ersterer Stelle ein fortgesetztes Knistern im Eise, das nicht dem gewohnten Geräusch bei der Hebung und Senkung der Eisdecke durch die Gezeiten glich, sondern von genau derselben Art war, wie wir es später auf dem Inlandeise im Westen der Station vernahmen. Den deutlichsten Beweis für eine Bewegung liefern aber die Eiskuppeln, d. h. isolierte Erhebungen des Untergrundes, die vom Eise lediglich vermöge seiner horizontalen Be-

Fig. 6. Zerklüftung am Südende der Schnauder-Ø. Mai 1907; Wegener phot.

wegung noch überquollen werden, so dass sich hier eine beulenförmige Erhebung der Eisoberfläche zeigt, die stark mit Spalten durchsetzt ist. Wir kamen bis auf wenige Hundert Meter an eine solche Eiskuppel heran, die ca. 15 Km südlich der Ostspitze von Lamberts-Land liegt. Die Erhebung dieser Kuppel über die Umgebung betrug etwa 30 M, und sie war so voller Spalten, dass man nicht ohne Gefahr näher herangehen konnte. Wie um das Verständnis dieser Erscheinung zu erleichtern, ragte nur wenige Kilometer südlich hiervon eine ganz eisfreie, aber stark abgeschliffene Klippe ca 50—100 M über die Eisoberfläche hervor. Bei einem früheren höheren Eisstande muss diese Klippe einen ganz ähnlichen Eisbuckel über sich erzeugt haben. Ein anderer ganz entsprechender Eisbuckel liegt in dem Sunde, der die Schnauder-Ø von der kleinen ihr nördlich vorgelagerten Insel trennt. Später wird noch mehrfach von derselben Erscheinung aus nördlicheren Gegenden berichtet werden.

Diese spaltenreichen Eisbuckel dürften einen völlig einwandfreien Beweis für die fortschreitende Bewegung des Eises bilden. In der Tat ist eine solche Bewegung von vornherein ausserordentlich wahrscheinlich, wenn man den gewaltigen Gletscher betrachtet, der südlich von Lamberts-Land auf die Bucht hinabfliesst und hier also fortwährend einen neuen Nachschub von Eis liefert. Offenbar wird die Eismasse der Jökelbugt nach aussen hin immer flacher und stellt dieselbe Erscheinung dar wie eine Gletscherzunge, bei welcher nach aussen hin die Abschmelzung immer mehr überwiegt.

Die Ursache dieser fortschreitenden Abflachung ist leicht ein-

Fig. 7. Schraubung im schwimmenden Inlandeise. Jökelbugten, Juni 1907; Koch phot.

zusehen. Eine Inlandeismasse, die dauernd ohne Bewegung auf dem Meere schwimmt, muss offenbar nach und nach zu derjenigen Dicke herabschmelzen, welche bei den vorhandenen klimatischen Verhältnissen als stationär (abgesehen von der stets unvermeidlichen Jahresschwingung) gelten kann. Dass dies eine viel geringere Dicke ist als die des Inlandeises, sehen wir an dem Meereise, dessen Dicke ja eben das Produkt dieser klimatischen Verhältnisse ist. Erst wenn das Inlandeis sich bis auf die Dicke des Meereises ausgeflacht hat, kann der Zustand stationär werden.

Es liegt auf der Hand, dass bei der Abschmelzung diejenige von oben (durch die Luft bezw. Sonnenstrahlung) und diejenige von unten (durch das Wasser) zusammenwirken. Der Betrag dieser Abschmel-

zung von unten wird natürlich von mancherlei lokalen Bedingungen, namentlich den Temperatur- und Strömungsverhältnissen des Wassers, abhängen, doch geht man wohl nicht fehl in der Annahme, dass er wenigstens an manchen Orten die Abschmelzung von oben erheblich übertrifft. Diese Verhältnisse sind namentlich deshalb von Interesse, weil auf diese Weise die unteren, Grundmoräne führenden Schichten des Eises sehr schnell aufgelöst werden müssen, so dass sich unter dem schwimmenden Inlandeis schon in verhältnismässig kurzer Zeit bedeutende Ablagerungen auf dem Meeresboden bilden können.

Möglicherweise stehen die eigentümlichen Wogen, welche die Eisoberfläche auf der Jökelbugt in manchen Partien ausgebildet hat, gleichfalls mit der fortschreitenden Bewegung in Zusammenhang. Diese Oberflächengestaltung entspricht ganz den langgezogenen flachen Wogen, die von Nansen und anderen beim Aufstieg auf das Inlandeis gefunden worden sind. Die Höhendifferenz beträgt zwischen Berg und Tal meist ca 10 M, während die Wellenlänge von Berg zu Berg mehrere Hundert Meter beträgt. Die Richtung der Wogen variiert vielfach, jedoch scheinen sie mit Vorliebe, wenn nicht ausschliesslich, so orientiert zu sein, dass sie senkrecht zur Bewegungsrichtung streichen. Es sind folgende Notizen über derartige Wogen gemacht worden:

Zwischen Hagens-Ø und dem Nordre-Depot wurden Wogen getroffen, die sich durch geringe Höhe auszeichneten, indem die Höhendifferenz bei ihnen nur 2—3 M betrug. Vielleicht hängt dies mit der hier offenbar nur geringen Dicke des Eises zusammen. Die Streichrichtung dieser Wogen war anscheinend N—S, was jedoch als unsicher bezeichnet ist.

Südlich der Schnauder-Ø wurden Wogen getroffen, deren Höhendifferenz meist nur 3—5 M betrug, bisweilen aber auf 10—15 M stieg, während die Wellenlängen zwischen 300 und 1500 M variierten. Die Streichrichtung war hier nicht konstant, als mittlere Richtung wäre etwa NW—SE zu bezeichnen.

An der Westseite der Schnauder-Ø und der kleinen Insel im Norden davon wurden Wogen von 200—300 M Wellenlänge und einer Höhendifferenz von 10—15 M gefunden, deren Streichrichtung SzE—NzW war.

Südlich von Lamberts-Land, also nördlich des eben genannten Gebietes, wurden sehr grosse Wogen getroffen, von denen aber nur die Streichrichtung NW—SE notiert wurde.

In allen diesen Fällen scheint die Streichrichtung der Wogen senkrecht zur Bewegungsrichtung des Eises zu liegen (wenngleich sich über die letztere an manchen Stellen nur Mutmassungen aufstellen lassen), was — soweit bekannt — auch für die älteren Beobachtungen von

dem auf dem Lande liegenden Inlandeise zutrifft. Diese Eigentümlichkeit legt die Annahme nahe, dass es sich hier jedenfalls um eine Erscheinung handelt, die unmittelbar durch die fortschreitende Bewegung des Eises erzeugt wird. Die regelmässige Wiederholung der Wogen lässt insbesondere die Vermutung nicht ganz unberechtigt erscheinen, dass es sich hier um ein Erzeugnis der Jahresperiode, sei es der Dickenschwankung oder der jährlichen Periode der Bewegung handelt. Sollte sich diese Vermutung bestätigen, so könnte man aus der Wellenlänge dieser Wogen eine ungefähre Vorstellung von dem Betrag der jährlichen Bewegung erhalten.

Für die Frage, ob und wieweit dies schwimmende Inlandeis noch

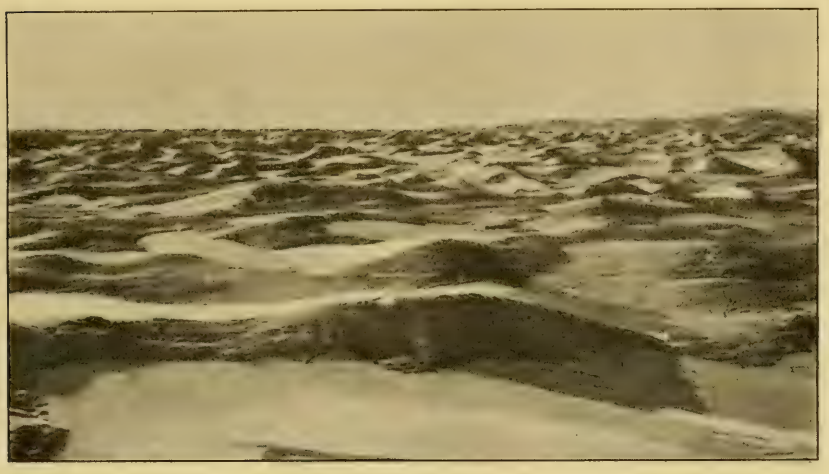


Fig. 8. Schmelzhöcker auf dem schwimmenden Inlandeise. Jökelbugten, April 1907; Wegener phot.

an Ort und Stelle einen Zuwachs durch Niederschlag erhält, sind namentlich die Beobachtungen von Wichtigkeit, die im Frühjahr 1907 bei der Hauptschlittenreise in Bezug auf die Schneebedeckung dieses Gebietes gemacht wurden. Die Niederschlagsbeobachtungen am Winterhafen lehrten nämlich, dass $^4/_5$ des Jahresniederschlags im Winter fällt, so dass die Schneebedeckung im Frühjahr durchaus massgebend für die Gesamtniederschlagsverhältnisse ist. Auch in der Jökelbugt zeigte sich das allgemeine Gesetz bestätigt, dass sich längs der Küste auf dem Meere ein Abräumungsgebiet infolge der hier eintretenden Verdichtung der Stromlinien bei NW-Wind ausbildet[1]). Hier kann sich nicht nur kein Treibschnee ansammeln, sondern auch der bei Windstille gefallene Schnee wird durch den nächsten stärkeren

[1]) Vergl. das Kapitel „Niederschlag“ in: Meteorologische Terminbeobachtungen am Danmarks-Havn, Danmark-Exp. etc. II No. 4.

Wind wieder fortgeschafft, so dass selbst im Frühjahr, zur Zeit der grössten Schneebedeckung, die blanke Eisoberfläche zu Tage liegt. Diese Eisoberfläche zeigte dann die für die „Randzone" charakteristischen Schmelzhöcker (Fig. 8), welche später bei der Besprechung des auf dem Lande liegenden Inlandeises eingehender beschrieben werden sollen. Mit zunehmender Entfernung von der Küste nahm die Schneebedeckung immer mehr zu und erreichte bei grösserer Annäherung an die Inselkette eine den normalen Jahresniederschlag sicherlich erheblich überschreitende Höhe. Auf der Luvseite der Inseln hatten sich — wieder ganz entsprechend dem im Danmarks-Havn gewonnenen Schema — excessiv mächtige Schneeablagerungen gebildet, offenbar weil die Stromlinien der Luft hier auseinandertreten, und die langsamer bewegte Luft nicht mehr soviel Treibschnee führen kann wie früher. Im Frühjahr 1908 wurde so an der Westseite der Schnauder-Ø eine Schneehöhe von ca 10—20 M konstatiert. Auf dieser mächtigen Neuschneedecke, die im Frühjahr 1907 den grössten Teil des schwimmenden Inlandeises bedeckte, wurde während der Reise noch eine eigentümliche Erscheinung beobachtet, indem alle Augenblicke unter der Last des Schlittens eine grössere Schneescholle mit einem merkwürdigen seufzerähnlichen Laut sich senkte, was bei dem darauf gehenden Menschen das momentane Gefühl erzeugte, als versinke er in eine Spalte, während bei den Hunden charakteristischerweise jedesmal eine Art Panik ausbrach. Offenbar war der Schnee in den tieferen Schichten bereits stark zusammengesunken, während die oberste Kruste, die widerstandsfähiger war, stehen geblieben war, so dass sich unter ihr flache, aber ausgedehnte Hohlräume gebildet hatten.

Auch an der Nordküste von Norske-Ø scheint noch ein anderes kleineres Areal Inlandeis zu liegen, welches mit der übrigen Inlandeismasse wohl nicht in Zusammenhang steht (vergl. die Karte 1 : 1000000).

KAPITEL II.

Der Gletscher zwischen Lamberts-Land und Hovgaards-Ø.

Auch auf der Nordseite von Lamberts-Land schiebt sich durch den Nioghalvfjerds-Fjord ein grosser Eisstrom ins Meer, dessen Breite (ca. 30 Km) nur wenig geringer ist als die seines südlichen Nachbars. Dieser Gletscher wird aber schon vor Erreichung der Aussenküste durch Abzweigung eines Seitenarmes nach Norden in den Dijmphna-

Fig. 9. Lager neben der Schraubung nördlich von Lamberts-Land. April 1907; Wegener phot.

Sund in seiner Produktivität beeinträchtigt. Gleichwohl ist die Tatsache überraschend, dass weder der Hauptgletscher noch der Nebenarm kalbt, dass vielmehr beide Teile auch hier in flachen Zungen endigen. Hierdurch gewinnen die Verhältnisse viel Ähnlichkeit mit denen in der Jökelbugt.

Die Grenze des unebenen Treibeises zieht sich vor dieser Bucht ungefähr in gerader Linie von Norske-Ø nach der Südost-Ecke von

Hovgaards-Ø. Westlich dieser Linie liegt zunächst eine ebene, anscheinend nicht aufbrechende Meereisdecke. Der Übergang von hier zum Inlandeise war wegen der sehr starken Schneebedeckung im Frühjahr 1907 nicht mit Sicherheit zu ermitteln, doch spricht vieles dafür, dass eine grosse Schraubung (Fig. 9), die von Brönlunds-Grav ungefähr über die halbe Bucht hinüber nach Norden reicht, diese Grenze repräsentiert. Von Norden her zieht sich eine entsprechende Schraubung nach Süden, aber ohne die erstgenannte zu erreichen. An dieser Grenzlinie liegen mehrere kleine Schären, und zwar einige ziemlich dicht westlich der südlichen, einige andere ein paar Kilometer östlich der nördlichen Schraubung. Das Eis beginnt westlich dieser Linie eine schwach wogenförmige Oberfläche anzunehmen. Nur an einer einzigen Stelle westlich der nördlichen Schraubung lag die blanke Eisoberfläche zu Tage und zeigte hier wie früher die Schmelzknollen. Sonst war dieser Zungenrand des Gletschers überall von tiefem Schnee bedeckt. Auf diesem Gebiet wurden auch mehrere grosse Steine gefunden, die ganz isoliert auf der Eisoberfläche lagen und aus der Entfernung für Seehunde gehalten wurden. Offenbar sind sie als die Ausläufer irgend einen Moräne von sehr sporadischer Struktur aufzufassen.

Etwas weiter aufwärts, nach Westen zu, bildet der Gletcher ein grosses System von Querspalten aus, welche für unsere Schlitten weder eine Passage von unten herauf noch von oben herab gestatteten. Die Spalten hatten die Richtung Nord—Süd, einige kleinere waren aber in Ost—West orientiert. Als wir von Nordwesten kommend hier den Weg durch diese Spalten versperrt fanden, schätzten wir ihre Tiefe zu 15—20 M, ihre Breite meist zu 30 M. Der Boden war hier wieder gefrorenes Meerwasser, wie bei einer Spalte festgestellt werden konnte. Wir hatten den Eindruck, als hätten wir hier diejenige Partie des Gletschers vor uns, wo das Eis den Boden verliert und zu schwimmen beginnt, indessen konnten unzweideutige Wahrnehmungen hierüber nicht gemacht werden. Die Seiten dieser Spalten zeigten fast immer eine Niveaudifferenz; meist — wenn auch nicht stets — war die Ostseite niedriger, oft bis 5 M. Als wir am Westrande dieser Spalten entlang nach Süden fuhren, kamen wir auch hier wieder über ein lokal begrenztes Abräumungsgebiet, wo die blanke Eisoberfläche in Gestalt von Schmelzhöckern zu Tage lag. Bevor wir jedoch Lamberts-Land erreichten, mussten wir etwa 10 Km vor demselben noch eine eigentümliche, parallel dem Lande verlaufende Schraubung passieren, die uns deswegen zu denken gab, weil ihre Landseite sehr erheblich niedriger lag als diejenige, auf der wir gekommen waren. Leider sind unsere Beobachtungen aus dieser Gegend zu unvollständig, um eine abschliessende Erklärung hierfür

geben zu können. Vermutlich handelt es sich um eine Diskontinuität in der Bewegung des Eisstromes, bei welcher der schneller bewegte (landfernere) Teil im Laufe des Winters auch stärker angeschwollen war als der relativ unbewegte Teil am Lande.

Es ist nicht unwahrscheinlich, dass Mylius-Erichsen mit seinen Begleitern bei ihrem verhängnisvollen Abstieg vom Inlandeise in das soeben geschilderte Spaltensystem hineingeraten und auf diese Weise verhindert worden sind, das so nahe gelegene Depot auf Lamberts-Land zu erreichen.

Auch der in den Dijmphna-Sund mündende Arm dieses Gletschers kalbt nicht, obwohl das Fjordeis vor ihm im Sommer wohl gänzlich verschwinden dürfte, er endigt vielmehr ebenfalls in einer flachen Zunge. Beim Übergang vom Meereise auf diese Zunge hatten wir eine unbedeutende Schraubung zu passieren. Dieselbe dürfte vielleicht als Gezeitenschraubung, vielleicht aber auch nur als ein Produkt des winterlichen Vorstosses der Gletscherzunge aufzufassen sein. Letztere scheint, wenigstens in ihrem vordersten Teile, zu schwimmen, jedenfalls steht sie nicht in festem Zusammenhang mit dem Ufer von Hovgaards-Ø, sondern ist durch einen kanalartigen Streifen Meerwassers, dessen Eisdecke damals stark zertrümmert und geschraubt war, vom Ufer getrennt.

Beim Herauffahren auf die Zunge zeigte sich, dass die Eisoberfläche sehr schnell bis etwa 10 M Höhe anstieg und die bekannten Schmelzhöcker aufwies. Weiter südlich war sie jedoch mit ebenem Schnee bedeckt und erreichte bald 15—20 M Höhe über dem Meere. Am südlichen Ausgange des Sundes liegen nahe der Küste von Hovgaards-Ø mehrere der oben besprochenen spaltenreichen Eisbuckel. Daneben befindet sich auch hier eine einzelne, das Eis überragende Klippe, deren Durchmesser kaum mehr als 100 M betragen dürfte.

Unter dem Eise scheint ein Höhenrücken die SW-Ecke der Hovgaards-Ø mit dem nördlichsten Punkt von Lamberts-Land zu verbinden. Wir kamen etwa auf der Mitte dieser Strecke schräg über eine mit kleinen Spalten durchsetzte Aufwölbung des Eises, die sich nach beiden Seiten weit in der Richtung Nordost—Südwest erstreckte. Nahe östlich von ihr beginnt dann das oben erwähnte grosse Spaltensystem.

KAPITEL III.

Das Inlandeis auf dem Lande westlich der Station.

Etwa 150 Km westlich der Winterstation liegt ein 1500—2000 M hohes Gebirge (Dronning-Louises-Land, vergl. Karte 1:500000) welches ganz vom Inlandeis umgeben ist. Das Eis strömt an seiner Nordseite vorbei und teilt sich hier in zwei Arme, von denen der kleinere sich nach Norden wendet und in der Jökelbugt endigt, während der Hauptstrom, Storströmmen, nach Süden fliesst und nach Vereinigung mit dem Bistrup-Bræ, der das Gebirge von Süden her umströmt, in der Dove-Bugt als Brede-Bræ aufs Meer hinaustritt. Dieser Brede-Bræ endigt mit einer bis zu 30 M hohen Steilwand und ist sehr produktiv; der Fjord vor ihm sowie der Sund zwischen Edwards-Ø und Carl-Hegers-Ø war so mit Eisbergen gefüllt, dass man kaum mit dem Schlitten zwischen ihnen hindurchgelangen konnte. Ein Teil dieser Eisberge gelangt durch die zahlreichen Sunde hindurch in die Dove-Bugt hinaus, von wo einzelne nördlich um Store-Koldewey herum zum Meere hinaustreiben. Fig. 10 zeigt einen solchen Eisberg, der

Fig. 10. Eisberg — 36 M hoch — in der Stormbugt, vom Brede-Bræ stammend. Juni 1907; Wegener phot.

in der Stormbugt festgekommen war; seine Höhe wurde zu 36 M gemessen. Der grösste Teil der vom Brede-Bræ stammenden Eisberge

Fig. 11. Gletscher-Stirn in Ardencaple-Inlet. Mai 1908; Jarner phot.

wandert indessen nach Süden zwischen Haystack und dem Südende von Store-Koldewey hindurch; an letzterem Punkte stehen die Eis-

Fig. 12. Gletscher-Stirn in Ardencaple-Inlet. Mai 1908; Jarner phot.

berge fast ebenso dicht gedrängt auf dem Grund, wie unmittelbar vor dem Brede-Bræ.

Ein anderer produktiver Gletscher ist der Soranerbræ westlich

von Teufelkap; seine Steilwand ist nur einige Meter hoch, er produziert in folgedessen nur Kalbeis. Die übrigen kleinen Gletscher, die weiter südlich im Bessels-Fjord und Ardencaple-Inlet bis zum Meer herabreichen, sind für die Eisbergproduktion ganz ohne Bedeutung.

Das Inlandeis wurde auf der Danmark-Expedition namentlich auf zwei Schlittenreisen im Frühjahr 1908 näher untersucht. Die eine derselben, die im März 1908 ausgeführt wurde, benutzte den Sälsö als Reiseroute und überquerte von dessen innerstem Ende aus den ca 40 Km breiten Eisstrom, Storströmmen, bis zum Dronning-Louises-Land. Die andere, die im Mai 1908 ausgeführt wurde, gelangte auf dem Annekssö bis zum Rande des Eises und überquerte dies bis zum Ymers-Nunatak, der dem Dronning-Louises-Land im Norden vorgelagert ist. Das bereiste Gebiet zeigte fast überall eine äusserst geringe Schneebedeckung und bot beinahe alle Erscheinungen der typischen Randzone, wie sie bereits wiederholt aus West-Grönland[1]) beschrieben worden sind. Im folgenden sollen die auf den beiden Reisen gemachten Beobachtungen getrennt besprochen werden.

1. Die Schlittenreise vom Sælsö zum Dronning-Louises-Land (Märzreise).

Am westlichen Ende des Sælsö zweigt sich ein kleiner Gletscher vom Inlandeise ab und mündet kalbend im See (Fig. 13). Auf unserer

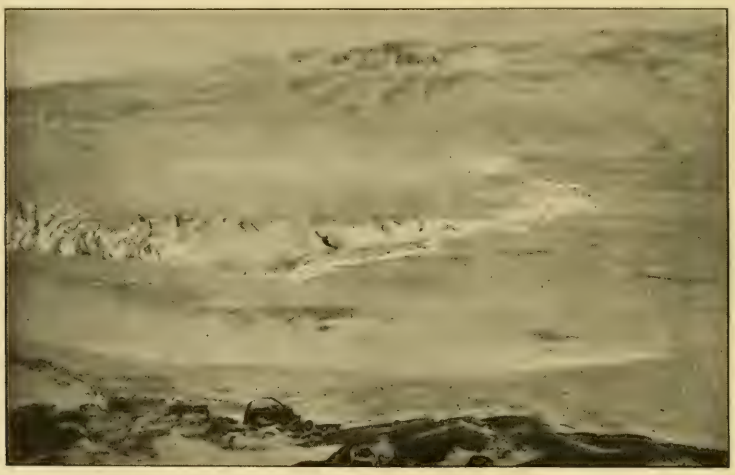


Fig. 13. Sælsö-Gletscher. März 1908; Wegener phot.

Reise hatten wir schon im mittleren Teil des Sees einige kleine, stark abgeschmolzene Reste von Kalbeis gefunden, die offenbar Überbleibsel

[1]) z. B. von Jensen in Meddel. om Grönl. I, pag. 17; Garde in Meddel. om Grönl. XVI; Nordenskjöld, Peary, Nansen, de Quervain u. a.

der Produktion dieses Gletschers vom Sommer 1906 darstellten. Am westlichen Ende des Sees fanden wir weitere 5 Stücke Kalbeis von frischerem Aussehen, die sich offenbar erst im Sommer 1907 vom Gletscher abgelöst hatten. Nach Schätzung hatte der über dem Wasser befindliche Teil dieser Kalbeisstücke durchschnittlich eine Grundfläche von 15 Quadratmeter bei einer Höhe von 2 M, wonach man sich ein ungefähres Bild von der Produktivität machen kann.

Die Front des Gletschers war offenbar im Lauf des Winters erheblich vorgerückt, denn sie hatte die ca 2 M mächtige Eisdecke des Sees[1]) in grossen Falten vor sich hergeschoben. Etwa 200 M vor der Front lag eine Stirnmoräne im See, die sich z. T. über die Oberfläche desselben erhob und einen vom südwestlichen Ende des Sees halbkreisförmig in diesen hineinweisenden Wall darstellte.

Fig. 14. Eisdecke des Sælsö, vom Vorrücken des Gletschers gefaltet. März 1908; Wegener phot.

Am nordöstlichen Seitenrand des Gletschers, der eine ca 20 M hohe (nicht kalbende) Steilwand darstellt, erschien das Eis auf einer längeren Strecke, aus der Entfernung gesehen, vollständig schwarz. Beim Herantreten konnte man erkennen, dass es durch und durch mit Lehmpartikeln und selbst grösseren Steinen durchsetzt war, und dass das Eis selber überall sehr arm an Luftblasen und deshalb durchsichtig war, wodurch das dunkle Aussehen noch verstärkt wurde. Sogar auf der Oberfläche des Eises lagen hier noch einige grössere Steine, die herausgeschmolzen waren, und die ganze Oberfläche war mit einer dünnen Lehmschicht bedeckt. Es handelte sich hier offenbar um die vom Eise eingeschlossene Grundmoräne, die durch vertikale Bewegungskomponenten an dieser Stelle bis zur Oberfläche des Eises hinaufgeführt wurde.

[1]) 2 Messungen, welche Trolle allerdings im östlichen Teil des Sees ausführte, ergaben 2.12 resp. 1.76 M Dicke.

Dieser Gletscher bot den Reisenden einen Aufstieg auf das Inlandeis, welches sonst, soweit man sehen konnte, mit einer schwer besteigbaren Steilwand von ca 15—20 M Höhe gegen das Land endigte. Auch an dieser Steilwand war noch eine ähnliche lokal begrenzte schwarze Stelle sichtbar, in welcher die Grundmoräne bis zur Oberfläche des Eises anstieg.

Der Gletscher selbst war von zahlreichen Spalten durchsetzt. In dem Masse aber, wie wir uns der Oberfläche des eigentlichen Inlandeises näherten, wurden die Spalten immer geringfügiger und verschwanden schliesslich ganz. Genau auf der Mittellinie des Gletschers war eine grabenartige, meist mit Schnee gefüllte Rinne erkennbar,

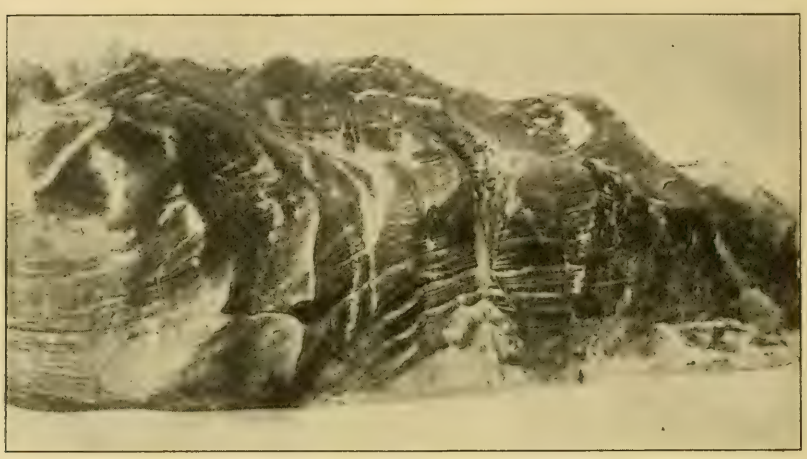


Fig. 15. Schwarzer Rand des Inlandeises nahe des Sælsö. März 1908; Lindhard phot.

welche vermutlich im Sommer das Bett eines Oberflächenbaches bildet.

Sowohl am Ostrand des Gletschers, wie an dem südwestlich des letzteren liegenden Steilrand des Inlandeises liess sich ein System von niedrigen, parallel dem Eisrande auf der Oberfläche verlaufenden Kämmen von durchsichtigerem, blasenfreiem Eise erkennen, die uns veranlassten, die Eisoberfläche mit einem Krokodilsrücken zu vergleichen. Dieselbe Erscheinung wurde später auch am Eisrande bei Dronning-Louises-Land wiedergefunden, während sie auf der Zwischenstrecke fehlt. Diese Kämme sind anscheinend identisch mit den „Ogiven" der Alpengletscher[1]) und stellen die Blaubänderstruktur dar. Die Erhebung der Kämme über ihre Umgebung betrug selten mehr als $^1/_2$ M.

[1]) Vergl. Hess, die Gletscher, Braunschweig 1904, pg. 169.

Fig. 16. Schwarzer Rand des Inlandeises beim Austritt auf den Sælsö. März 1908; Wegener phot.

Fig. 17. Spalte im Inlandeise in der Nähe des Sælsö-Gletschers. März 1908; Wegener phot.

An unseren Zeltplätzen auf der Oberfläche dieses ca 40 Km breiten Eisstromes zwischen Dronning-Louises-Land und dem Sælsö konnten wir fast immer, wenn wir darauf Acht gaben, ein leises Knistern hören, das aus dem Eise zu kommen schien und wohl auf fortgesetzte Bildung kleiner Spalten zurückzuführen ist.

Die Eisoberfläche war auf der ganzen von uns bereisten Strecke, und soweit wir sie nach rechts und links überschauen konnten, überall mit den schon früher erwähnten Schmelzhöckern bedeckt, welche allmählig von Osten nach Westen an Grösse zunahmen, während gleichzeitig die Schneebedeckung in derselben Richtung

Fig. 18. Die ersten Schmelzhöcker auf dem Inlandeise. März 1908; Wegener phot.

abnahm. Der Höhenunterschied zwischen Berg und Tal wuchs successive von $^1/_2$ M im östlichen auf 3—4 M im westlichen Teil (Mittelwerte).

Für die Entstehung dieser Schmelzhöcker scheinen zwei sich entgegenwirkende Faktoren massgebend zu sein: die Abschmelzung durch Sonnenstrahlung und durch warme Luft. Da nämlich die Sonnenstrahlung durch Wasser stark absorbiert, von trockenem Eise aber grösstenteils reflektiert wird, so muss sie besonders stark in den schon vorhandenen Vertiefungen wirken, in denen sich Schmelzwasser ansammelt. Es würde hieraus also eine allgemeine Tendenz zur Verstärkung schon vorhandener Unebenheiten der Eisoberfläche resultieren. Wenn dieser Faktor allein wirksam wäre, so müsste offenbar die Eisoberfläche im Laufe der Zeit in einen Wald von Eis-

nadeln und -Türmen zerfallen, wie Koch es übrigens auf den isländischen Gletschern im Jahre 1904 in der Tat nicht selten beobachten konnte. Diesem Prozess wirkt aber offenbar die Schmelzung durch

Fig. 19. Zeltlager auf dem Inlandeise. Im Hintergrunde „Wogen". März 1908; Wegener phot.

warme Luft entgegen, denn diese wirkt naturgemäss am stärksten auf die Erhöhungen der Eisoberfläche. Die Schmelzhöcker würden hiernach einen Kompromiss, eine Art Gleichgewichtsgestalt zwischen diesen beiden Faktoren darstellen.

Fig. 20. Kämme und Täler auf dem Inlandeise. März 1908; Wegener phot.

Im östlichen Teil schienen diese Schmelzknollen jeder Regelmässigkeit zu entbehren. Im mittleren und westlichen Teil aber zogen sie sich in kurze, von E nach W gerichtete Kämme aus, die bis-

weilen in packender Weise einem plötzlich erstarrten wogenden Meer glichen. Es ergab sich kein bestimmter Anhalt dafür, ob diese Bevorzugung der E—W-Richtung durch die Bewegungsrichtung des Eises (hier N—S), durch die vorherrschende Windrichtung (gleichfalls annähernd N—S) oder durch die Orientierung zur grössten Höhe der Sonne oder endlich durch Kombinationen dieser Einflüsse bedingt ist. Das Profil der Wogen zeigte einen steileren schneefreien Abhang nach N und einen sanfteren mit Schnee bedeckten nach S.

Nur wenige Kilometer vom Ostrande des Inlandeises entfernt

Fig. 21. 15 M hoher Kamm. März 1908; Wegener phot.

trafen wir ein lokal begrenztes System von höheren parallel verlaufenden Kämmen, die nur wenige 100 M lang waren und nach WNW wiesen, jedoch mit einer nach N konvexen Biegung (Fig. 20 und 21). Diese Kämme waren wohl bis 15 M hoch, und die zwischen ihnen liegenden Täler waren durch gefrorene Schmelzwasserlachen ausgefüllt. Unsere Auffassung von ihrer Entstehung sei durch folgende beim Rückweg hier an Ort und Stelle niedergeschriebene Tagebuchnotiz wiedergegeben: „Wir durchquerten die Zone (der hohen Kämme) sehr nahe an ihrem südlichen Ende. Die Kämme sind hier mehr niedergeschmolzen. Die Höhe wird daher bald sehr gering, sie verschwinden kurz südlich von unserem Kurs. Nördlich davon (beim Hinweg lag unsere Route etwas nördlicher) machen die Kämme einen

mehr frischen Eindruck. Wahrscheinlich werden sie noch weiter nördlich in ein frisches Spaltensystem übergehen".

Fig. 22. „Krater" auf der Oberfläche des Inlandeises. März 1908; Lindhard phot.

Mitten auf unserem Marsche nach dem Dronning-Louises-Land stiessen wir auf ein eigentümliches Gebilde, das wohl nur durch die Annahme zu erklären ist, dass hier im Sommer eine starke Quelle die Schmelzwässer an die Oberfläche des Eises befördert (Fig. 22). Auf einer etwa 3 M hohen Erhebung der Eisoberfläche befand sich ein teilweise eingestürzter Krater, dessen oberster Rand etwa 10 M über dem allgemeinen Niveau lag. Die Nordostseite war am besten erhalten und stellte eine nach innen überhängende Eisgrotte dar. In der Mitte lagen die Reste der eingestürzten Decke. Der Boden des Kraters aber, der aus spiegelblankem Schmelzwassereis bestand, zeigte bereits wieder eine konische, von den Seiten nach der Mitte zu ansteigende Erhebung. Wir gewannen den Eindruck, als ob die jetzt eingestürzte Kraterdecke nichts anderes sei als der Kraterboden des Vorjahres, der infolge der allgemeinen Abschmelzung scheinbar in die Höhe gewachsen war. Sollte dies zutreffen, so würde daraus folgen, dass die jährliche Abschmelzung ca 4 M beträgt. An der Westseite zeigte der Kraterrand einen Einschnitt, der offenbar den Abfluss darstellte.

In der Nähe des Westrandes des Inlandeises trafen wir auch noch andere Oberflächenerscheinungen, namentlich einen kleinen, tief eingeschnittenen See, sowie das gefrorene Bett eines Oberflächenbaches (Fig. 26). Auch am Dronning-LouisesLand, bei Kap Bellevue, bestand der Rand des Eises aus einer fast senkrechten Mauer, deren Höhe auf 25 M geschätzt wurde, und die jedenfalls überall erheblich höher war als diejenige am Ostrande. Wir gingen $1^1/_2$ Stunden oben auf dieser Steilwand entlang, bis wir eine Schneewehe fanden, die einen Abstieg auf das Land ermöglichte (Fig. 23). In einer Einbuchtung des Landes lag zwischen Land und Eis ein kleiner zu dieser Jahreszeit gefrorener

Fig. 23. Rand des Inlandeises am Dronning-Louises-Land bei Kap Bellevue. Das Eis ist ganz frei von Grundmoräne und besteht aus sehr dünnen, fortwährend auskeilenden Schichten. Im Vordergrunde die Schneewehe, die den Abstieg zum Lande ermöglichte. März 1908; Wegener phot.

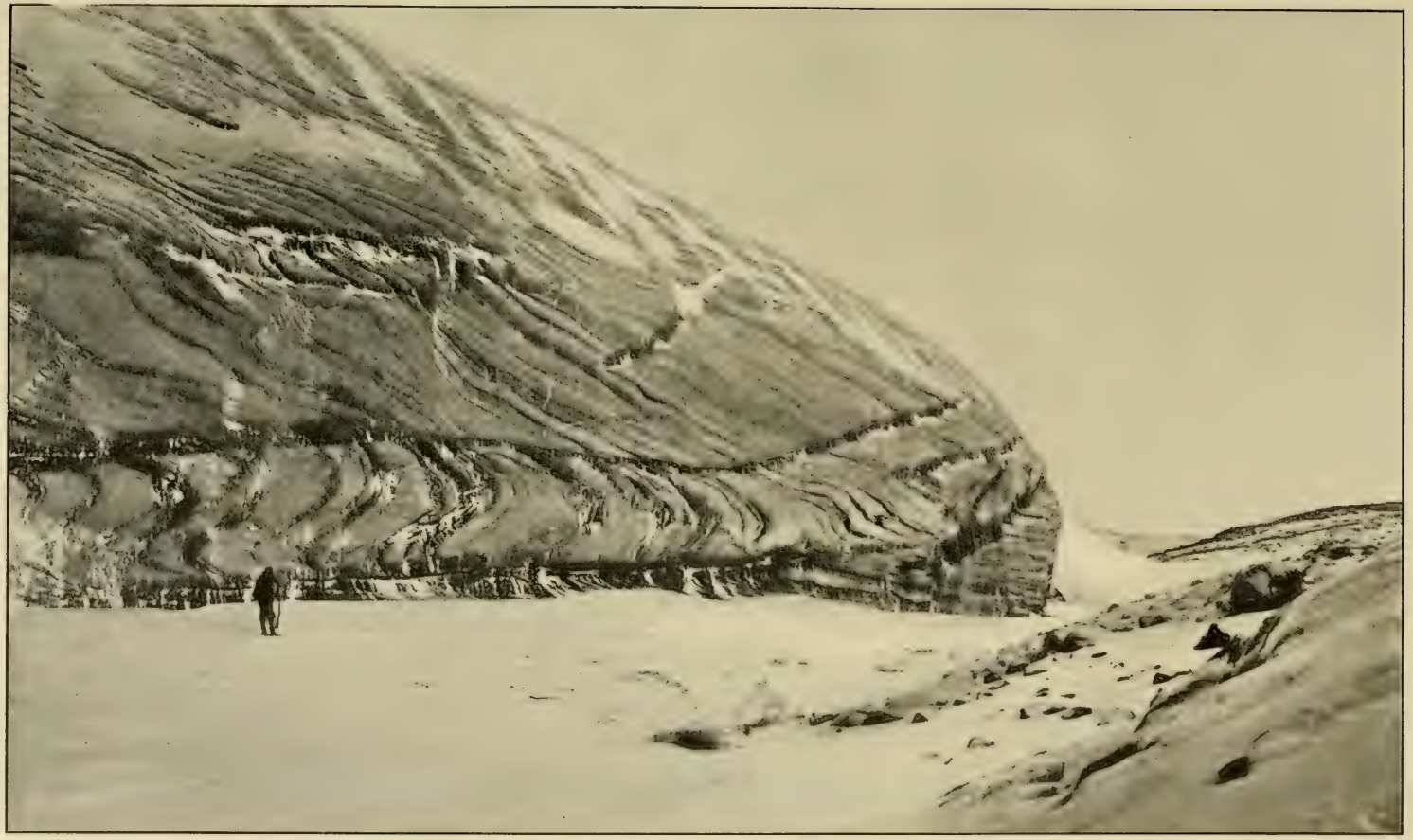


Fig. 24. Rand des Indlandeises bei Kap Bellevue. Gebogene Schichtung und Scherungsflächen. Die dunklen Schichten bestehen nicht aus Grundmoräne, sondern nur aus blasenfreiem, durchsichtigem Eis. Rechts hinten die Abstiegs-Schneewehe. März 1908; Wegener phot.

Fig. 25. Randsee mit Eisbergen auf Dronning-Louises-Land westlich Kap Bellevue. März 1908: Wegener phot.

Randsee. Der Eisrand, soweit wir ihn sehen konnten, zeigte nirgends die später zu beschreibenden Schichten von Grundmoräne, das Eis war vielmehr überall vollständig rein.

Fig. 26. Das Bett eines Oberflächenbaches. März 1908; Wegener phot.

Der von uns betretene Teil des Dronning-Louises-Landes bildet eine nach N vorspringende Halbinsel. An ihrer der Eisbewegung entgegen gerichteten N-Seite war die Eiswand ganz vertikal, und vor ihrem Fuss lagen einige abgesprengte Eistrümmer (Fig. 24). Im Nord-

Fig. 27. Sporadische Moräne auf dem Inlandeise. März 1908; Lindhard phot.

westen von dieser Halbinsel strömt das Inlandeis in einen grösseren See hinab, den es dicht mit Eisbergen anfüllt (Fig. 25). Auch jenseits des Sees war ein grosser Gletscher, von NW herabsteigend, zu sehen, der offenbar in den fast verdeckten nordwestlichen Teil des Sees mündet.

Etwa eine Meile östlich von Dronning-Louises-Land lag auf dem Eise eine sehr sporadische Moräne, die genau von Norden nach Süden gerichtet war (Fig. 27). Spätere Beobachtungen machen es sehr wahrscheinlich, dass dieselbe identisch ist mit derjenigen Moräne, die von dem noch zu besprechenden Ymers-Nunatak zunächst mit südöstlicher Richtung entspringt und dort zugleich eine Senkung im Eise darstellt, die den zahlreichen Randseen am Nunatak bei hohem Wasserstande Abfluss gewährt. Auch hier im Süden stellte die Moräne noch eine Talsenkung von 10—15 M Tiefe dar, doch war hier ein ganzes System solcher parallelen Täler vorhanden, die alle von N nach S wiesen und also zu den oben beschriebenen kleineren Schmelzwällen und Wogen senkrecht verliefen. Die Moräne war über mehrere dieser Täler zerstreut, in einer Gesamtbreite von ca 200—300 M, und bestand hauptsächlich nur aus einzelnen grossen Blöcken mit unverletzten Bruchkanten, die ausserordentlich zerstreut auf der Eisoberfläche lagen. Gekritztes Geschiebe war nur wenig vorhanden.

Auf der Rückreise wurde mitten auf dem Inlandeise eine Beobachtung über das Korn des die Oberfläche bildenden Eises gemacht. Beim Hineinwerfen eines Eisstückes in heisses Wasser konnte man deutlich erkennen, dass die Körner ca $^1/_2$ Cm Durchmesser besassen.

Aus den Nivellements, die an den verschiedenen Stationen auf dem Eise ausgeführt wurden, ergab sich die auf den ersten Blick überraschende Tatsache, dass die Oberfläche des Eises auf der ganzen Strecke von E nach W nur ausserordentlich wenig ansteigt und die Seehöhe von 300 M nicht wesentlich überschreitet.

Die Schneebedeckung war, wie schon eingangs erwähnt wurde, äusserst gering, und es unterliegt keinem Zweifel, dass nicht nur aller Schnee, sondern auch noch eine beträchtliche Eisschicht hier in jedem Sommer abschmilzt. Zahlenangaben für die Schneemenge konnten wir wegen der unregelmässigen Ablagerung des Schnees in den Vertiefungen nicht ermitteln. Doch dürfte die mittlere Schneehöhe für das bereiste Gebiet erheblich geringer sein als am Danmarks-Havn.

2. Die Schlittenreise vom Annekssö nach Ymers-Nunatak (Maireise).

Bei der zweiten Schlittenreise, die den Annekssö als Reiseroute benutzte, gestaltete sich der Aufstieg aufs Inlandeis erheblich leichter. Das Eis hat an dieser Stelle, gerade in dem toten Winkel zwischen dem nach N und dem nach S gehenden Strom, keine starke Bewegung und endigt wohl aus diesem Grunde nicht in einer Steilwand, sondern in einem flachen, leicht besteigbaren Schneeabhang. Die Schnee-

Fig. 28. Randzone des Inlandeises. Schmelzhöcker. Mai 1908; Koch phot.

bedeckung des Eises war auf dieser Linie zwar anscheinend etwas stärker, als weiter südlich (an einigen Punkten wurde sogar noch vorjähriger Schnee konstatiert), doch gehört auch dies Gebiet noch ganz der Randzone an. Im letzten Drittel des Weges nach Ymers-Nunatak nahm die Schneebedeckung aber bereits etwas zu, ein Zeichen dafür, dass man sich der Firngrenze des Inlandeises näherte, die vermutlich mit dem Westende des Nunataks zusammenfallen dürfte.

Kochs Schlittenreise erfolgte im Mai 1908 vom Annekssö nach Südwesten neben dem Kofoed-Hansens-Bræ entlang, den man als ausgeprägten Strom im Inlandeis etwa 70 Km weit nach dem Innern

Fig. 29. Schmelzhöcker auf dem Inlandeise. Mai 1908; Koch phot.

verfolgen kann. Der Uebergang zwischen dem gänzlich unpassierbaren Strom und dem ruhigen Eis ist recht plötzlich. Wir konnten dem Rande des starken Stroms in etwa 1 Km Abstand folgen.

Wir beabsichtigten ursprünglich, Dronning-Louises-Land dicht nördlich von dem Punkt zu erreichen, den die Märzabteilung besucht hatte. Aber schon ca 30 Km bevor wir das Land erreichten, gebot uns Storströmmen Halt, welcher hier ebenso unpassierbar wie der Kofoed-Hansens-Bræ zu sein schien. Wir wurden auf diese Weise nach Westen in einen zwischen beiden Eisströmen gelegenen Streifen gedrängt, der an der schmalsten Stelle kaum 1 Km breit war (das Tagebuch gibt an „ein paar hundert Meter").

Die Steigung des Eises bis zu Ymers-Nunatak ist aus den Höhenangaben der Karte zu entnehmen. Wenn man von der ersten Steigung unmittelbar am Erdboden absieht, bekommt man als Mittelwert für

die Neigung der Oberfläche bis Ymers-Nunatak ungefähr 1 : 150 = ca 24′. Die Steigung ist indessen nicht gleichmässig. Das Eis hebt sich in drei grossen Terrassen, von denen die westlichste, die unmittelbar westlich von Ymers-Nunatak liegt, die bedeutendste ist und

Fig 30. Schneegefüllte Transversalspalte in Storströmmen nahe bei Jættebrinken. Mai 1908; Koch phot.

eine Höhe von über 1500 M erreicht. Die Oberflächen der Terrassen steigen zwar im ganzen nach Westen; aber an einzelnen Stellen kann man doch eine nicht unerhebliche Neigung nach Westen antreffen, die zur Genüge beweist, dass die Eisoberfläche östlich von Ymers-Nunatak bis zu einem gewissen Grade sich dem Relief des Erdbodens anschmiegt.

Die Schmelzknollen hatten auf diesem Teil des Inlandeises ganz

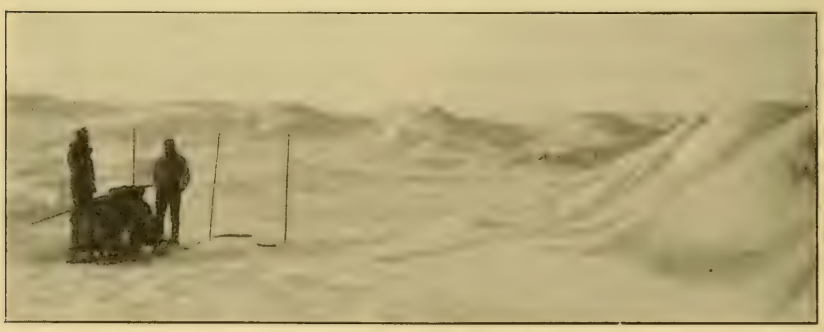


Fig. 31. Storströmmen nahe bei Jættebrinken. Im Hintergrunde schneegefüllte Transversalspalten. Mai 1908; Koch phot.

dasselbe Aussehen wie weiter im Süden. Gewöhnlich schien, wie Figur 28 zeigt, keinerlei System in ihrer gegenseitigen Stellung vorhanden zu sein; aber an solchen Stellen, wo das Eis so stark zerklüftet war oder gewesen war, dass es aus einzelnen Eisrippen mit zwischenliegenden, schneeerfüllten Senkungen bestand, gewährten die Schmelzknollen natürlich den Eindruck, als ob sie parallel zu den

Spalten in Reihen geordnet wären. Es kann wohl kein Zweifel sein, dass diese Schmelzknollen dieselbe Erscheinung bilden, welche J. A. D. Jensen von dem Inlandeis östlich von Frederikshaabs-Isblink beschrieben hat. (Medd. om Grönland I, S. 54, sowie Tafel 1). Dass die Schmelzknollen dort im Süden (ca 62° 40′) nahe der Davisstrasse bedeutend stärker entwickelt sind, ist nur natürlich. Die Temperatur ist dort höher und die Abschmelzung deshalb stärker; gleichzeitig ist wohl auch die Verdampfung bei der Nähe der Davisstrasse relativ geringer.

Etwa 5 Km östlich von Ymers-Nunatak trafen wir ein System

Fig. 32. Spalte im Inlandeise, teilweise mit Schnee gefüllt. Mai 1908; Koch phot.

gewaltiger Querspalten, welche durch 10—15 M hohe Eiskämme getrennt waren, die ganz das Aussehen der von der Märzabteilung gesehenen hatten. Die Kämme verliefen von West-Süd-West nach Ost-Nord-Ost; sie hatten eine schwache Krümmung, deren konvexe Seite nach West-Nord-West gerichtet war. Der Abhang der Kämme nach Ost-Süd-Ost (d. i. in der Bewegungsrichtung des Eises) bildete eine gleichmässige, fast ebene Eiswand, während die Rücken selber und ihr Abhang nach West-Nord-West mehr uneben und unregelmässig war. Die Täler zwischen den Eiskämmen waren bis zu 50 M breit, ihr Boden bestand aus festem Schnee. [Ähnliche Formen solcher Kämme sind auch auf Island bekannt; doch sind sie hier viel kleiner, wohl kaum mehr als ein paar Meter hoch.]

Der Uebergang zwischen dem ebeneren Eis und den Kämmen vollzog sich auf einer Strecke von etwa 1 Km. Zunächst bildete das Eis kleine raupenförmige Erhebungen mit geringen schneeerfüllten Senkungen dazwischen; aber nach und nach wurden die „Raupen" höher und schärfer, und die Senkungen tiefer und breiter, bis man sich schliesslich zwischen den höchsten Kämmen befand. Die Täler, welche offenbar früher Querspalten waren, keilten nach etwa 1—2 Km Länge aus. In dem inneren Teil dieser Einschnitte, wo die Eiswände sich einander näherten, war der Schnee am Boden sehr unregel-

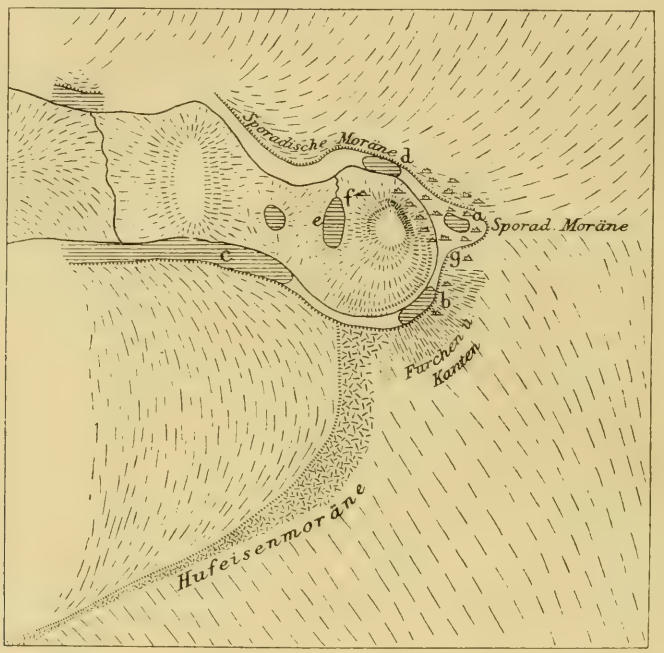


Fig. 33. Kartenskizze von der Umgebung von Jættebrinken. Nach einem Kroki von Koch, aufgenommen im Mai 1908.

mässig abgelagert; bisweilen gab es hier plötzliche tiefe Senkungen im Schnee, welche zeigten, dass die Spalten weit in das Eis hinein gingen.

Auch nachdem die scharfen Kämme sich wieder verloren hatten, setzten die Einschnitte in Gestalt schwach gesenkter Schneestreifen bis unmittelbar zu Ymers-Nunatak fort. Auf den letzten Kilometern, bevor wir den Nunatak erreichten, versuchten wir mehrmals, den Schnee in diesen Streifen zu durchbrechen und nachzusehen, ob darunter eine Spalte lag; es glückte aber nicht ein einziges Mal, hier die Anwesenheit von Spalten festzustellen.

Im übrigen waren wir auf der ganzen Reise bis unmittelbar an

die hohen Kämme heran durch frische Spalten belästigt worden. Dieselben waren gewöhnlich $^1/_2$—5 M breit, erreichten aber ausnahmsweise auch eine Breite von ca 30 M. Kleinere Spalten gab es ausserordentlich häufig, oft mit nur wenigen Metern Zwischenraum; sie waren gewöhnlich mit einer dünnen Schneeschicht bedeckt, welche zerbrach, wenn man sie betrat.

Fig. 34. Ein abgesprengter, auf Ymers-Nunatak gescheiterter Eisberg. Jættebrinken, Mai 1908; Koch phot.

Unsere Hoffnung, dass die zahlreichen Spalten uns Gelegenheit geben würden, die Struktur des Eises zu untersuchen, wurde getäuscht. Bei den offenen Spalten waren die Seitenwände überall mit einer Glasur von herabgeronnenem Schmelzwasser bedeckt (wie in Fig. 17), und bei den Spalten, die mit Schnee bedeckt waren, zeigte sich, dass die Struktur stets unter einer dicken Reifschicht verborgen war, was wohl auf die höhere Temperatur im Innern des Eises zurückzuführen ist.

Das Inlandeis endigte am Ymers-Nunatak überall mit einer Steil-

wand, an deren Fuss sich eine ganze Kette von Randseen befand (vergl. die Kartenskizze S. 34). Am tiefsten lagen die beiden Seen *a* und *b*; *c* und *d* lagen etwa 30 M über diesen, *e* weitere 10 M über diesen, also im ganzen 40 M über *a* und *b*.

Wir befanden uns am Ymers-Nunatak gerade zur Zeit der ersten Schneeschmelze. Am 18. Mai, dem ersten Tage, an dem wir Temperaturen über 0 hatten, konnte beobachtet werden, wie der die Verbindung zwischen *c* und *b* bildende Bach aufbrach. Auf letzterem See stieg das Wasser über seiner Eisdecke im Laufe einer halben Stunde um 2—4 Decimeter. Es war nicht zu bezweifeln, dass das Wasser des Baches über kurz oder lang die Kluft zwischen der Ostspitze von Ymers-Nunatak (Jættebrinken) und dem Inlandeis ganz ausfüllen und die Randseen zu einem grossen See verbinden musste, welcher unter günstigen Verhältnissen den Jættebrink ganz umgeben konnte und sich auch ostwärts über die Oberfläche des Inlandeises selbst weit hinaus erstreckte. Die Spuren eines solchen höheren Wasserstandes waren sehr deutlich. An dem mit Geröll bedeckten Bergabhang zwischen *a* und *b* waren sechs Strandlinien in einer Höhe bis zu 20—25 M (geschätzt) über dem Boden der Schlucht zu sehen; die grösste Höhe der Eiswand wurde hier auf ca 40 M geschätzt. An der Nordseite von Jættebrinken sah man noch eine einzelne Strandlinie hoch oben am Bergabhang. Die Steine am Fuss des Berges waren mit einer dünnen Lehmschicht überzogen. Eine so bedeutende Aufstauung von Wasser, wie hier anzunehmen war, musste eine Sprengung der Eismasse (Kalben) herbeiführen, wie es ja häufig in den Randseen stattfindet und auch bei dem von der Märzabteilung ca 30 Km weiter nach Südwesten angetroffenen Randseen der Fall war.

Die grosse Ausbuchtung, in welcher der See *a* liegt, war durch eine solche Sprengung geschaffen, deren Spuren noch deutlich erkennbar waren. Die Trümmer dieses abgesprengten Stückes lagen in Gestalt von gewaltigen Eisblöcken, von denen die grössten bis ca 20 M hoch waren, teils am Fusse vor der Eiswand, teils oben auf der Oberfläche des Eises (Fig. 35) oder in entsprechender Höhe auf dem gegenüberliegenden Abhange des Nunataks. So wurde z. B. an dem in der Kartenskizze mit *f* bezeichneten Punkte, der 45 M über *a* liegt, ein 6 M hoher Eisblock gefunden.

Da die Grundmoräne bei Jættebrinken einen sehr bedeutenden Teil der ganzen Eismassen erfüllt, ist es nicht unwahrscheinlich, dass das Gewicht der untersten Eisschichten grösser als das des Wassers ist. Dies könnte die Erklärung dafür geben, dass nicht die ganze Eismasse in der Ausbuchtung bei *a* fortgeschwemmt war, sondern die untersten Schichten grösstenteils am Boden des Sees liegen ge-

blieben waren. Grosse Stücke dieser Schichten waren allerdings gleichfalls fortgeschwemmt, wodurch in dem Eisboden selbst tiefe Senkungen mit vertikalen, zerrissenen Eiswänden gebildet waren.

Sowohl bei *a* wie bei *b* waren Senkungen im Inlandeis vorhanden, durch welche der See bei höchstem Wasserstand Abfluss erhalten konnte. Auf der Oberfläche des Eises befanden sich südöstlich von Jættebrinken drei beträchtliche Seen, deren grösster, welcher auf der Karte 1 : 500000 angedeutet ist, zu etwa 5 Km Länge veranschlagt wurde. Da indessen der Randsee bei *a* im Mai 1908 mindestens 30 M unter der Oberfläche der nächstliegenden Partie des Inlandeises lag, muss es also auch unter dem Eise noch einen Abfluss geben, dessen Länge dann wahrscheinlich 70—80 Km erreicht[1]).

Im Winter muss ein solcher Kanal leicht durch den Treibschnee geschlossen werden können, und es ist wohl denkbar, dass mitunter mehrere Jahre vergehen können, bis er sich wieder öffnet; die erwähnten 6 Strandlinien sprechen jedenfalls für stark variierende Verhältnisse in dieser Hinsicht.

Schliesslich ist noch ein Beispiel einer, wie es scheint, in diesen Gebieten nicht ungewöhnlichen Erscheinung zu erwähnen, nämlich der Eislawinen, die durch Frostsprengung herbeigeführt werden. Während wir den Abstieg über die schräge Eiswand nördlich von Jættebrinken rekognoszierten, wurde plötzlich einer der Eisblöcke gesprengt, die auf dem Inlandeise dicht neben dem Abhange standen. Die Sprengung fand nur ca 100 M von uns entfernt statt; wir hörten sie nicht nur, sondern sahen auch die Trümmer über die Eiswand herabstürzen, wo sie eine mehrere Meter breite und 1—2 Dezimeter dicke Schicht von wässerigem Schnee bildeten. Der Eisblock, dessen Volumen nach sehr flüchtiger Schätzung zu 50—100 Kubikmeter veranschlagt wurde, war mit einem Schlage vollständig in seine einzelnen Körner aufgelöst und bildete nun einen sehr wasserhaltigen Brei, der es uns ermöglichte, auf dem im übrigen recht steilen und glatten Eisabhange einigermassen festen Fuss zu fassen. Die Sprengung erfolgte um 4 Uhr nachmittags; an dem betreffenden Tage (17. Mai) herrschte kräftige Sonnenstrahlung; die Lufttemperatur betrug ÷2 C°, während sie an den beiden vorangehenden Tagen zwischen ÷10° und ÷20° C gelegen hatte.

Von grösstem Interesse aber waren die sehr merkwürdigen und auffallenden Formen, welche die steile Eiswand bei Ymers-Nunatak in der Umgebung von Jættebrinken zeigte, sowie die Beobachtungen über die darin enthaltene Grundmoräne, welche im folgenden beschrieben werden sollen.

[1]) Kornerup erwähnt in Medd. om Grönl. I einen Abfluss unter dem Eise von den Randseen bei Jensens-Nunatakker. Die Länge desselben muss dort je nach den Umständen zwischen 40 und 70 Km betragen.

Auf der Nordseite von Jættebrinken ist die Schlucht zwischen Bergabhang und Eiswand 200 bis 300 M breit. Die Wand ist hier steil, doch nicht vertikal (vergl. Fig. 35 und 48). Die oberste Partie der Wand schien mit einer Schale bedeckt zu sein, welche die Struktur verbarg; indessen hatte sich ein breiter horizontaler Schmutzstreifen durch die deckende Schale hindurch freigeschmolzen, und zahlreiche Schmelzwasserläufe hatten die Schale bis herab zum nächsten Schmutzstreifen gefurcht. Von hier abwärts lag die Struktur einige Meter breit zu Tage, bis das Eis am Grunde der Schlucht von einer Schneewehe verdeckt wurde.

Am Punkte *a* der Kartenskizze war die Schlucht stark verbreitert infolge der hier stattgefundenen Sprengung der Eismassen; dagegen verengerte sie sich zwischen *g* und *b* so stark, dass ihr Boden kaum mehr als 30 M breit war, und gleichzeitig stieg die Felswand ziemlich steil an, so dass die Eiswand hier nur kurze Zeit am Tage der direkten Sonnenstrahlung ausgesetzt sein konnte (Fig. 49).

Die Photographien 36, 37, 38, 39, 40 und 41 geben ein fast vollständiges Bild der Eiswand zwischen *g* und *b*; Fig. 42, 43 und 44 sind Detailbilder, erhalten bei *g*, mitten zwischen *g* und *b*, und bei *b*.

Besonders charakteristisch für diese Eiswand ist 1) ihr Mangel an Spalten, 2) ihre Furchung und 3) ihre deutlichen Grundmoräneschichten.

Es wurde schon oben erwähnt, dass wir auf dem Gebiet zwischen den hohen Kämmen und Ymers-Nunatak — also auf einem Streifen von ca 2 Kilometer Breite — trotz verschiedener Versuche, den Schnee in den schneeerfüllten Senkungen zu durchbrechen, nicht imstande gewesen waren, die Anwesenheit von Spalten festzustellen. Auch die soeben besprochene Eiswand nördlich von Jættebrinken hatte sich als völlig spaltenfrei erwiesen, und überhaupt wurde hier auf einer zusammenhängenden Strecke von ca 8 Km am östlichen Rande von Ymers-Nunatak nicht eine einzige offene Gletscherspalte gesehen (Die auf den Figuren 36, 37 und 42 sichtbare Spalte ist keine Gletscherspalte in gewöhnlichem Sinne; sie bildet die äusserste Grenze der Sprengung).

Dieser Umstand, dass alle Spalten trotz der in naher Nachbarschaft herrschenden starken Bewegung geschlossen sind, deutet darauf hin, dass an der Spitze des Nunataks eine Zusammenpressung des Eises stattfindet — was ganz natürlich ist, da hier die Eismassen zusammentreffen die auf den beiden Seiten des Nunataks herabströmen.

In diesem Zusammenpressen dürfte wohl auch die Erklärung für die Furchung der Eiswand zu suchen sein. Bei Punkt *g* der Kartenskizze — Fig. 36 und 42 — sind diese Furchen noch nicht zu

erkennen; zwischen *g* und *b* — Fig. 37 und 43 — treten sie allmählich auf; die stärkste Ausbildung erreichen sie bei *b* — Fig. 39, 40 und 44 — und verlieren sich darauf wieder zwischen *b* und *c* — Fig. 41 — Der Abstand von Kante zu Kante kann zu ca 1 M (geschätzt) angeschlagen werden. In der Nähe von Punkt *g* erscheint der Kanten-

Fig. 45. Durch den Randsee gesprengter Rand des Inlandeises nahe bei *a* (siehe Kartenskizze S. 34). Im Hintergrund rechts die „Hufeisenmoräne" zwischen Jættebrinken und dem kleinen Nunatak. Im Hintergrunde links Furchen und Kanten an der Oberfläche des Eises zwischen *g* und *b*. Mai 1908; Koch phot.

winkel stumpf — Fig. 43 —, während er bei *b* spitz wird — Fig. 39, 40 und 44.

Unser erster, unmittelbarer Eindruck war der, dass diese vertikale Furchung auf die Wirkung des Schmelzwassers zurückzuführen sei; doch ist dies offenbar unrichtig. Die übrigens sehr verschiedenartige Wirkung des Wassers auf die Eiswand ist u. a. deutlich auf Fig. 35 und 42 zu sehen; aber es ist schwer denkbar, dass Wasser auf dem Wege der Erosion im Eise so regelmässige und scharfe Kanten und Furchen hervorbringen könnte; und dass wir es

nicht etwa mit Eiszapfenbildungen (siehe hierüber weiter unten bei der Beschreibung der Eishöhlen) zu tun haben, sieht man klar aus dem Umstande, dass die vorspringenden Kanten gleichfalls Grundmoräneschichten enthalten. Wenn unsere Vermutung, dass die Kanten auf Druck zurückzuführen sind, richtig ist, müssten entsprechende Kanten und Furchen auch an der Oberfläche des Eises im rechten Winkel zur Richtung der Eiswand auftreten. Eine derartige Streifung der Oberfläche kann man in der Tat deutlich auf Fig. 45 erkennen. (Siehe auch Fig. 46 links).

Während die grösste Höhe der Eiswand zwischen Punkt *g* und *b* ungefähr 40 M (geschätzt) beträgt, ist sie bei *b* kaum grösser als 20 M; von hier nach Punkt *c* und weiter westwärts wird die Höhe über dem Boden der Schlucht noch geringer, und erreicht vielleicht nicht einmal mehr 10 M. Allerdings steigt der Boden der Schlucht selber, wie schon erwähnt, von *b* nach *c* um etwa 30 M (barometrisch gemessen). An der Stelle, wo die „Hufeisenmoräne" gegen Jættebrinken ausläuft, ist die Schlucht wohl zum Teil durch herabgestürzten Moränenschutt aufgefüllt, bildet aber auch hier noch eine scharfe Scheide zwischen Eiswand und Felsen.

Die Schichten im Eise steigen von *d* nach *a* (Fig. 35) und fallen langsamvon *g* nach *b*. Diesen Fall kann man auf Fig. 39 erkennen, wo an einer Stelle unmittelbar am Fuss der Eiswand ein kleiner Tümpel mit offenem Wasser zu sehen ist. Im ganzen verlaufen die Schichten parallel; bei *b* (ganz rechts in Fig. 39) scheint indessen eine Störung einzutreten, und der Parallelismus wird hier in den obersten Schichten durchbrochen. Die Schichtung im Eise kann man bis ganz hinauf zu den höchsten Partien desselben wahrnehmen; aber in dem obersten, nicht mehr vertikalen Teil der Eiswand — siehe Fig. 41 — scheint die Beschaffenheit des Eises eine andere zu sein als weiter unten; man bekommt hier, ebenso wie auf der Nordseite von Jættebrinken, ganz unmittelbar den Eindruck, als wäre der oberste, schräge Teil der Wand mit einer Schale von besonderer Natur bedeckt. Dagegen scheint an dem vertikalen Teil der Eiswand die innere Struktur überall zu Tage zu treten; nur ganz ausnahmsweise wird sie auch hier durch einen Eispanzer verdeckt, der mit der Struktur nichts zu schaffen hat (siehe Fig. 36 und 42 links oben).

Die durch v. Drygalski an der Westküste Grönlands beobachtete „polygonale Felderung" [1]) kommt ausserordentlich häufig und sehr stark ausgeprägt vor, namentlich in dem vertikalen Teil der Eiswand (Fig. 38). v. Drygalski meint, dass dieselbe der Wirkung des Wassers auf das Gletschereis entstammt, und dies stimmt vollkommen

[1]) E. v. Drygalski, Grönland-Expedition d. Ges. f. Erdk. zu Berlin, Berlin 1897, Bd. I, S. 491.

Fig. 46. Die „Hufeisenmoräne“ zwischen dem kleinen Nunatak und Jættebrinken. Mai 1908; Koch phot.

mit den Verhältnissen bei Ymers-Nunatak überein. Die Felderung kommt nicht nur an dem geschichteten Eise, sondern auch an der Schale fremden Eises vor, welches hier und da die Schichtung bedeckt (Fig. 36 und 42).

Die Grundmoräne reicht zwischen Punkt *a* und *g* (Fig. 36, 37 und 42) kaum höher als 6—8 M im Eise hinauf, ist aber dafür sehr dicht. Sie streckt sich zwar als zusammenhängende Eis- und Schmutzschicht die ganze Wand entlang; aber die Schmutzschichten gliedern sich in eine grosse Zahl oft kaum 1 Cm dicker Horizonte, die zwar parallel sind, aber doch häufig auskeilen und über einander greifen (Fig. 43)[1]), genau wie man es in den glacialen Kiesgruben sieht.

[1]) Vergl. v. Drygalski, a. a. o. S. 193 („Schichtung im Eise").

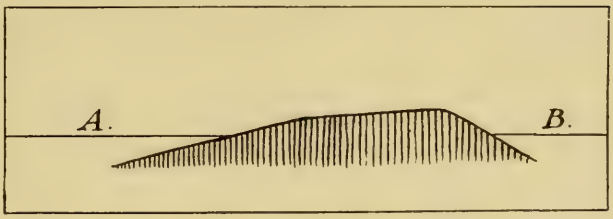


Fig. 47. Profil der „Hufeisenmoräne".

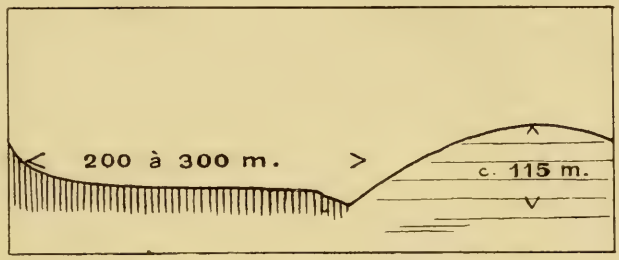


Fig. 48. Profil nördlich von Jættebrinken.

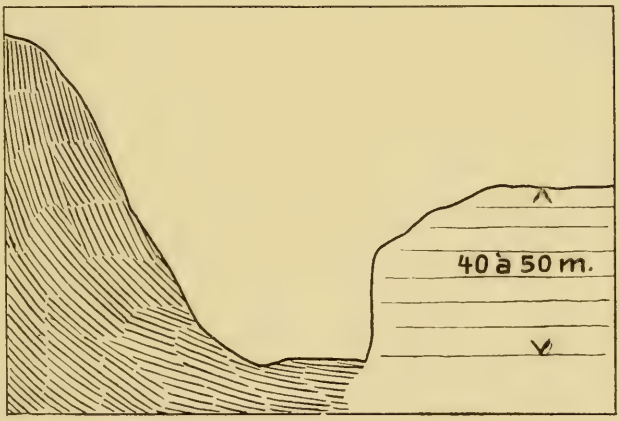


Fig. 49. Profil östlich von Jættebrinken.

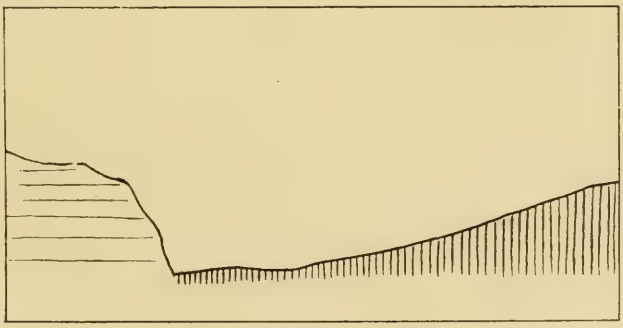


Fig. 50. Profil am Sælsö.

Da die Schichten nach Süden fallen und bei Punkt *b* teilweise schon unter dem Niveau des Sees verschwinden, sollte man erwarten, dass die Grundmoräne hier weniger hoch im Eise zu sehen wäre; dies ist aber keineswegs der Fall. Während gleichzeitig die vertikalen Kanten schärfer werden und weiter vorspringen, werden auch die Eisschichten in der Grundmoräne dicker, so dass die Schmutzschichten gehoben werden und auf diese Weise deutlich von einander getrennt als einzelne, wohl definierte dunkle Schichten zu liegen kommen (Fig. 40).

Längs der Nordseite von Jættebrinken ist eine ganz kleine Seitenmoräne auf der Oberfläche dicht über dem Eisabhange vorhanden; man kann sie auf Fig. 35 erkennen. Nur auf einer kurzen Strecke, nordöstlich des Sees *e* hat sie den Charakter eines zusammenhängenden Moränenwalles; sonst liegt ihr Material so zerstreut herum, dass sie das Eis nicht gegen die Abschmelzung zu schützen vermag. Das zerstreute Moränenmaterial lässt sich vom Randsee bei Punkt a in südöstlicher Richtung über das Eis hinaus noch weiter verfolgen und zieht sich die früher erwähnte Senkung entlang, in welcher die Oberflächenseen liegen. Dies ist offenbar dieselbe Moräne, welche von der Märzabteilung ca 25 Km weiter nach Südosten, 6—8 Km östlich Kap Bellevue, getroffen wurde.

Zwischen *b* und *c* endigt eine weitere Moräne, welche deswegen besonders merkwürdig ist, weil sie senkrecht zur allgemeinen Bewegungsrichtung verläuft (Fig. 33 und 46). Sie führt in einem hufeisenförmigen Bogen nach einem kleinen, im Südwesten gelegenen Nunatak hinüber und bildet einen zusammenhängenden Wall, dessen Breite zu etwa 200 M geschätzt wurde, während die Höhe 5—10 M betrug. Ihr Querschnitt hatte die in Fig. 47 dargestellte Form, wobei *A* die konvexe, *B* die konkave Seite des „Hufeisens" ist.

Derartige Moränen sind, soweit bekannt, zum ersten Male von Kornerup erwähnt[1]). Später wurden sie von Koch mehrfach auch auf Island am Südrande des Vatnajökull gefunden, wo sie an gewissen Stellen Seitentäler vollständig vom Haupttal absperren, während sie an anderen Orten Formen annehmen, welche sich den aus Grundmoräne gebildeten Mittelmoränen nähern[2]).

Schliesslich sei hier noch auf die umstehenden Profile des Eisrandes hingewiesen, die an Ort und Stelle, allerdings nur nach Augenmass, entworfen wurden. Des Vergleichs halber ist auch das Profil am Ostrand des Inlandeises beim Sælsö abgebildet.

[1]) Moræner ved Dalagers-Nunatakker: Medd. om Grönl. Bd. I.

[2]) Namentlich sei auf die beiden Blätter 97 NV und 87 NA der vom Dänischen Generalstab vermessenen Karte von Island (1 : 50000) hingewiesen, auf denen solche Moränen zu erkennen sind.

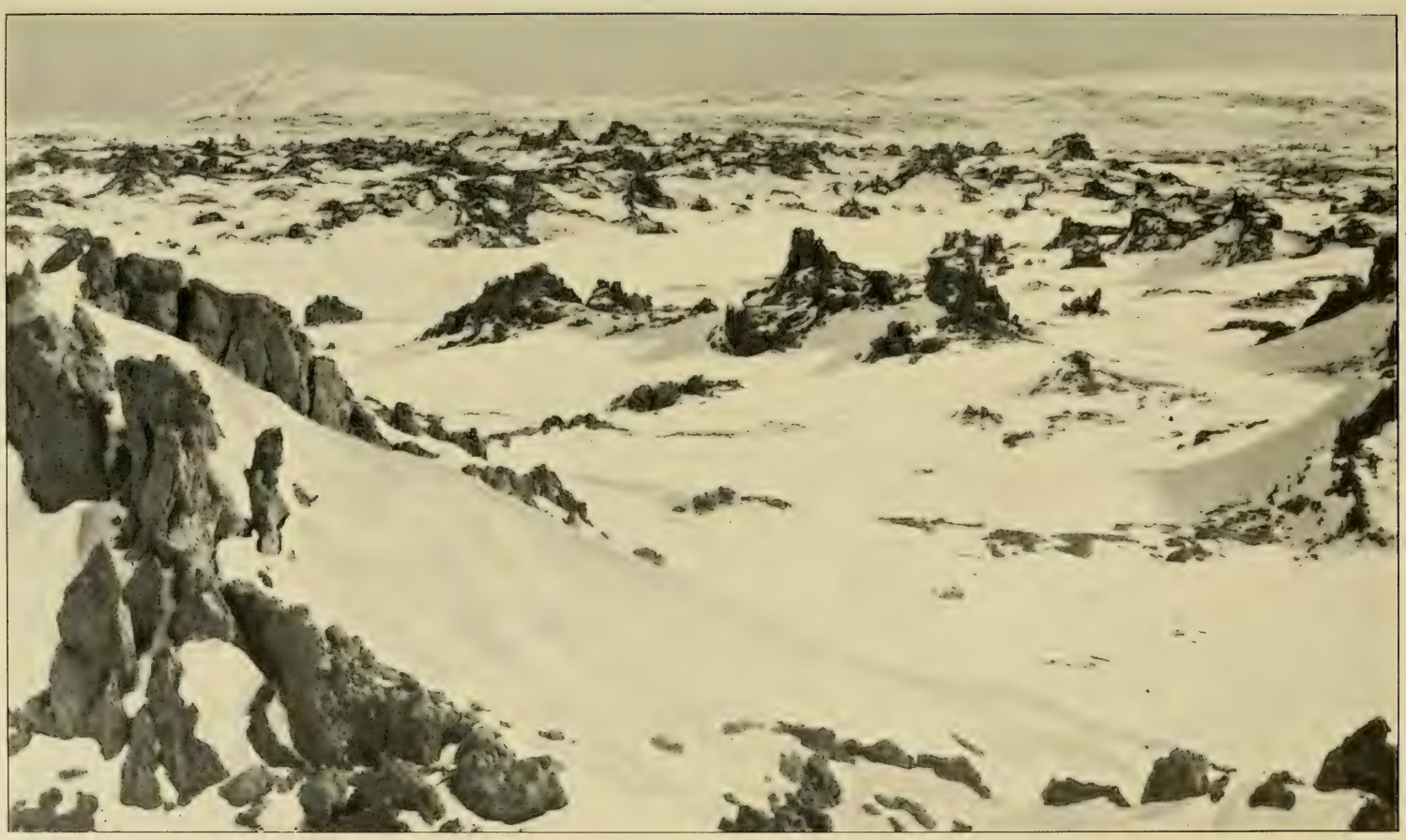


Fig. 51. Moränenlandschaft am Rande des Inlandeises. Mai 1908; Koch phot.

Fig. 52. An der Grenze zwischen Kofoed-Hansens-Bræ und der Moränenlandschaft. Mai 1908: Koch phot.

Fig. 53. Moränenlandschaft am Rande des Inlandeises. Mai 1908; Koch phot.

3. Die „Moræneland skab“ nordwestlich des Annekssö.

Die Höhe des Annekssö über dem Meere beträgt etwa 40 M. Vom Nordwest-Ende des Sees fällt das Terrain gleichmässig nach Westen zu bis zum Rande des Inlandeises, dessen Seehöhe ca 10 M beträgt, der sich aber schon wenige Kilometer weiter nördlich bis zum Meeresspiegel herabsenkt. Kofoed-Hansens-Bræ verbirgt also unter seinen Eismassen einen grossen Fjord, der sich von der Jökelbugt aus etwa 60 Km weit nach Süden erstreckt.

Fig. 54. Einzelner Turm aus der Moränenlandschaft. Mai 1908; Koch phot.

Vom Annekssö führt ein recht bedeutender Abfluss nach Nordwesten zum Eisrande, wo er umbiegt und am Eise entlang nach Nordost fliesst, um zusammen mit den Zuläufen von der Randschlucht südwärts mehrere kleine Randseen zu bilden und schliesslich unter dem Inlandeise zu verschwinden.

Nördlich des Annekssö hat die Randschlucht in den ersten 15 Km nicht die gewöhnliche Schluchtform, sondern besteht nur in einer 5 Km breiten Senkung, die langsam nach Osten ansteigt. Diese Senkung, deren Kontur auf der Karte 1 : 500000 angedeutet ist, bietet also kein nennenswertes Hindernis für eine Ausbreitung des Eises bis zu ihrer östlichen Grenze. Ihr Boden ist mit Moränenschutt erfüllt, welcher ein bröckeliges Sediment aus kalkhaltigem Sandstein, wechsellagernd mit bedeutenden Kohlenablagerungen, bedeckt. Obwohl also das Eis in früheren Zeiten die

Senkung ganz ausgefüllt hat, war es hier doch nicht imstande, dieses wenig widerstandsfähige Sediment fortzuerodieren, während es östlich von der Senkung und teilweise auch westlich vom Kofoed-Hansens-Bræ, wo das Terrain sich wieder bis auf mehrere Hundert Meter Seehöhe hebt, jede Spur von Sediment entfernt und die bekannte moutonnierte Gneislandschaft gebildet hat.

Die „Moræneland skab" hatte in dem südlichen Teil der erwähnten Senkung einen höchst eigentümlichen Charakter, der von den Photographien (Fig. 51—54) gut wiedergegeben wird.

Durch den Frühjahrsschnee nur teilweise verhüllt zeigten sich hier zahllose Türme und Pyramiden bis zu 10 M Höhe, die bei näherer Untersuchung aus Lehm bestanden, aber noch einen Kern aus Eis besassen. In der umstehenden Abbildung (Fig. 54) sieht man einen solchen einzelnen Turm, in dessen oberer Partie ein grosser Stein zu erkennen ist, dem wahrscheinlich die Erhaltung dieses Turmes zuzuschreiben ist. Ansammlungen grösserer Steine wurden überhaupt recht oft im obersten Teil der Türme bemerkt.

Die Türme ruhten auf einer Unterlage, die dicht am Eisrande schwach gewellt war, aber schon wenige Hundert Meter vom Eisrande entfernt den Charakter eines ganz flachen, horizontalen Plateaus annahm, dessen Oberfläche aus feinem geschichtetem Sand und Lehm bestand. Auch gröberes Geschiebe kam vor, aber dann stets als oberste Schicht in einer kleinen Erhöhung. Unterhalb der verhältnismässig unbedeutenden obersten Schicht aus eigentlichen Erdarten stiess man auf Gletschereis, welches mit Material der Grundmoräne in der gewöhnlichen, geschichteten Weise durchsetzt war. Dies Eisplateau war von Schluchten durchschnitten, die zum Teil den Charakter alter Gletscherspalten hatten, zum anderen Teil von Wasserläufen ausgegraben waren. Diese Spalten und Bachbetten waren 2—4 M tief und gaben damit offenbar die Dicke der Eismassen selber an, welche indessen in dem südwestlichen Teil der Moränenlandschaft beträchtlich grössere Mächtigkeit erreichten.

Man könnte versucht sein zu glauben, dass die herausgeschmolzene Schicht von Lehm und Sand bald eine solche Dicke erreichen müsste, dass sie das Eis gegen weitere Abschmelzung schützte; dies scheint jedoch nicht ganz zuzutreffen. An einem sonnigen Tag im Mai, bei einer Lufttemperatur von $\div 4°$, wurde der trockene Sand an der Oberfläche so warm, dass es eine Annehmlichkeit war, barfuss darauf zu gehen; aber am Nachmittage wurde er mehr und mehr von Feuchtigkeit durchtränkt, und nur der Platz, der vom Zelt bedeckt gewesen war, blieb trocken. Die Sonnenwärme ist also schon im Monat Mai im Stande, die deckenden Sand- und Lehmschichten zu durchdringen und eine Abschmelzung des obersten Teiles des Eises

Fig. 35. Rand des Inlandeises gegenüber Jættebrinken zwischen *a* und *d* (siehe Kartenskizze), bis oben hinauf mit Eistrümmern bedeckt. Moränenstreifen ganz oben links. Mai 1908; Koch phot.

Fig. 36. Rand des Inlandeises gegenüber Jættebrinken bei *g* (siehe Kartenskizze). Mai 1908; Koch phot.

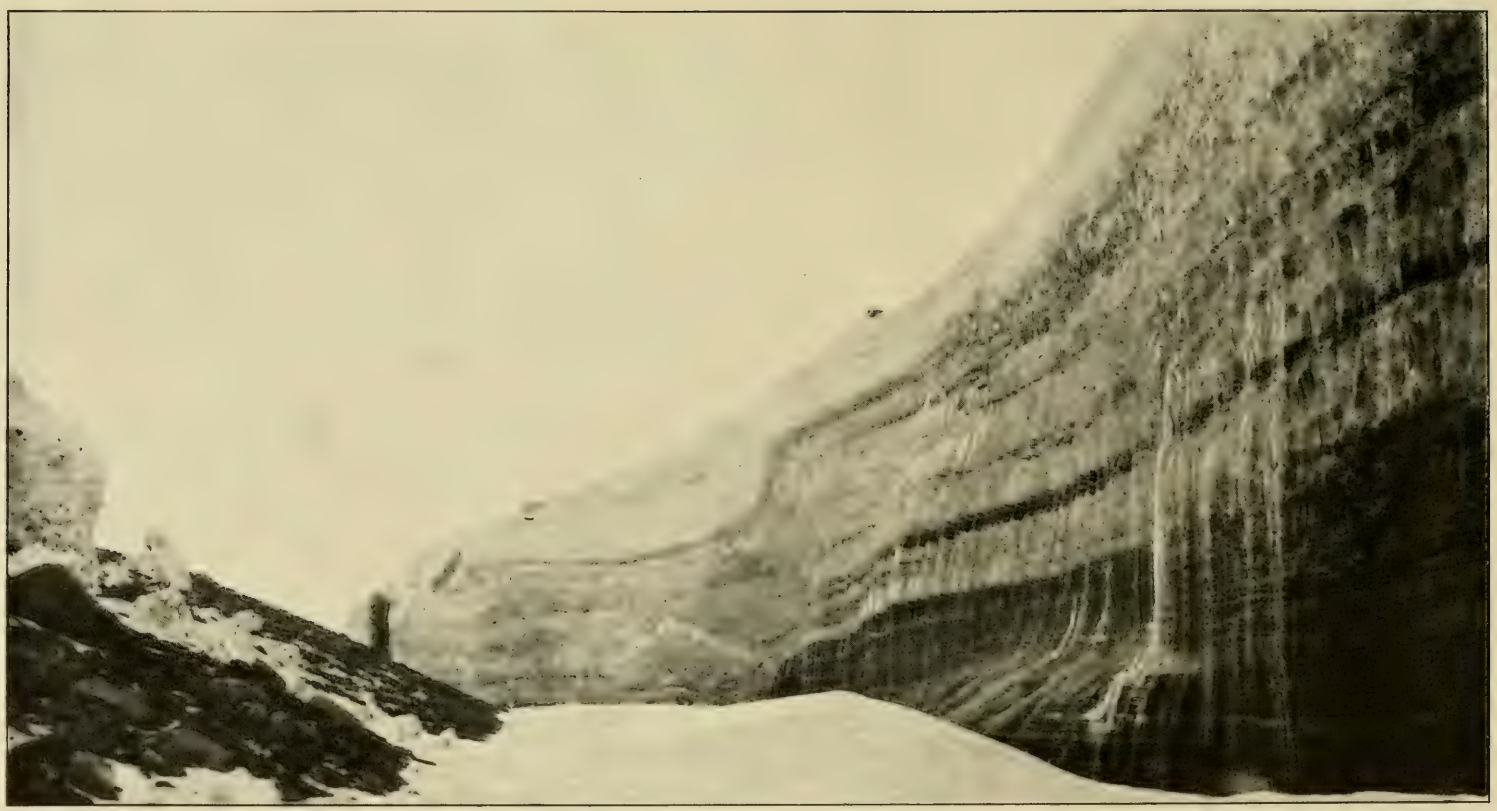


Fig. 37. Rand des Inlandeises gegenüber Jættebrinken zwischen *g* und *b* (siehe Kartenskizze). Mai 1908; Koch phot.

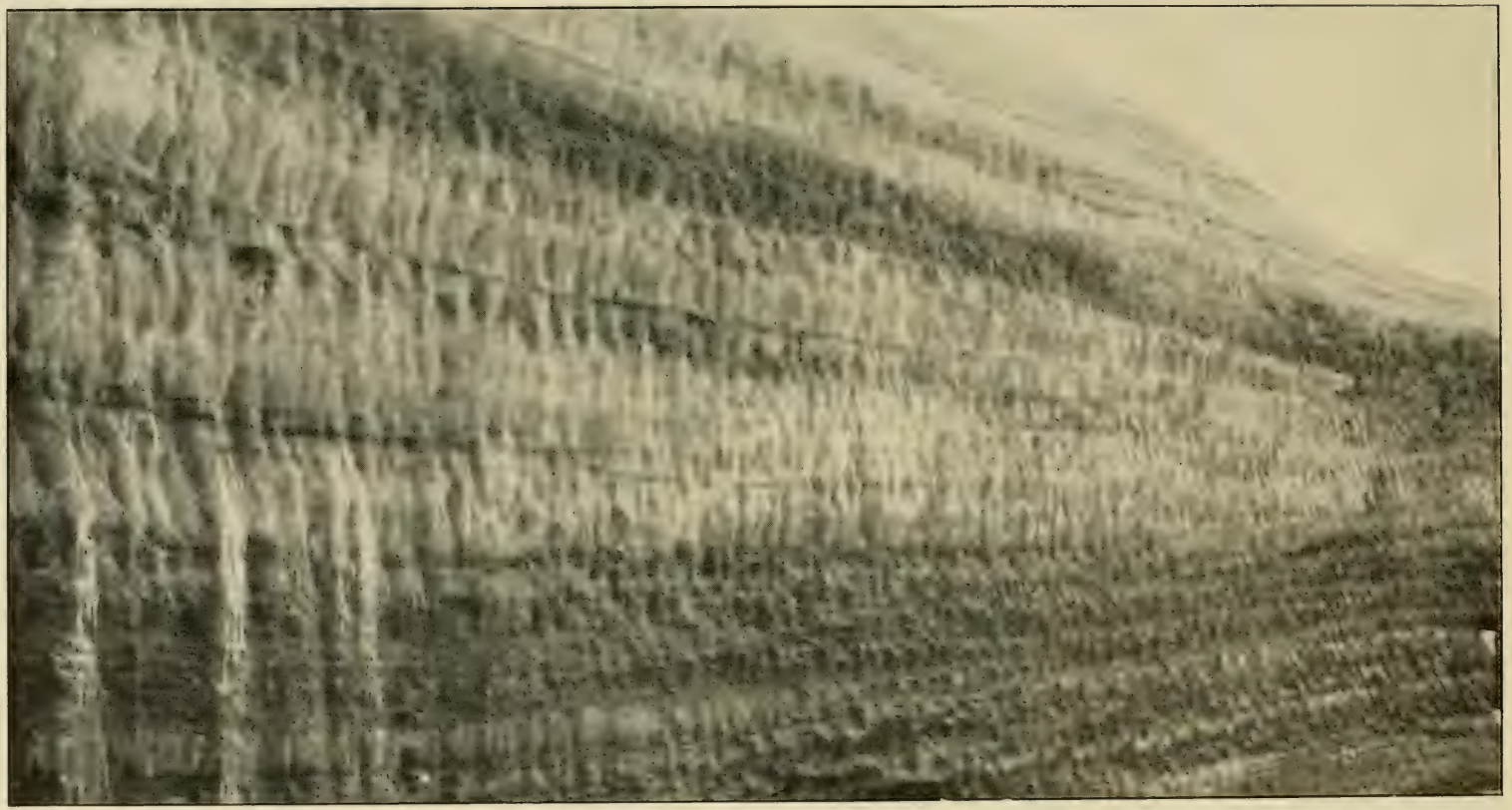


Fig. 38. Die 40 M hohe Steilwand des Inlandeises gegenüber Jættebrinken zwischen *g* und *b* (siehe Kartenskizze). Polygonale Felderung. Mai 1908; Koch phot.

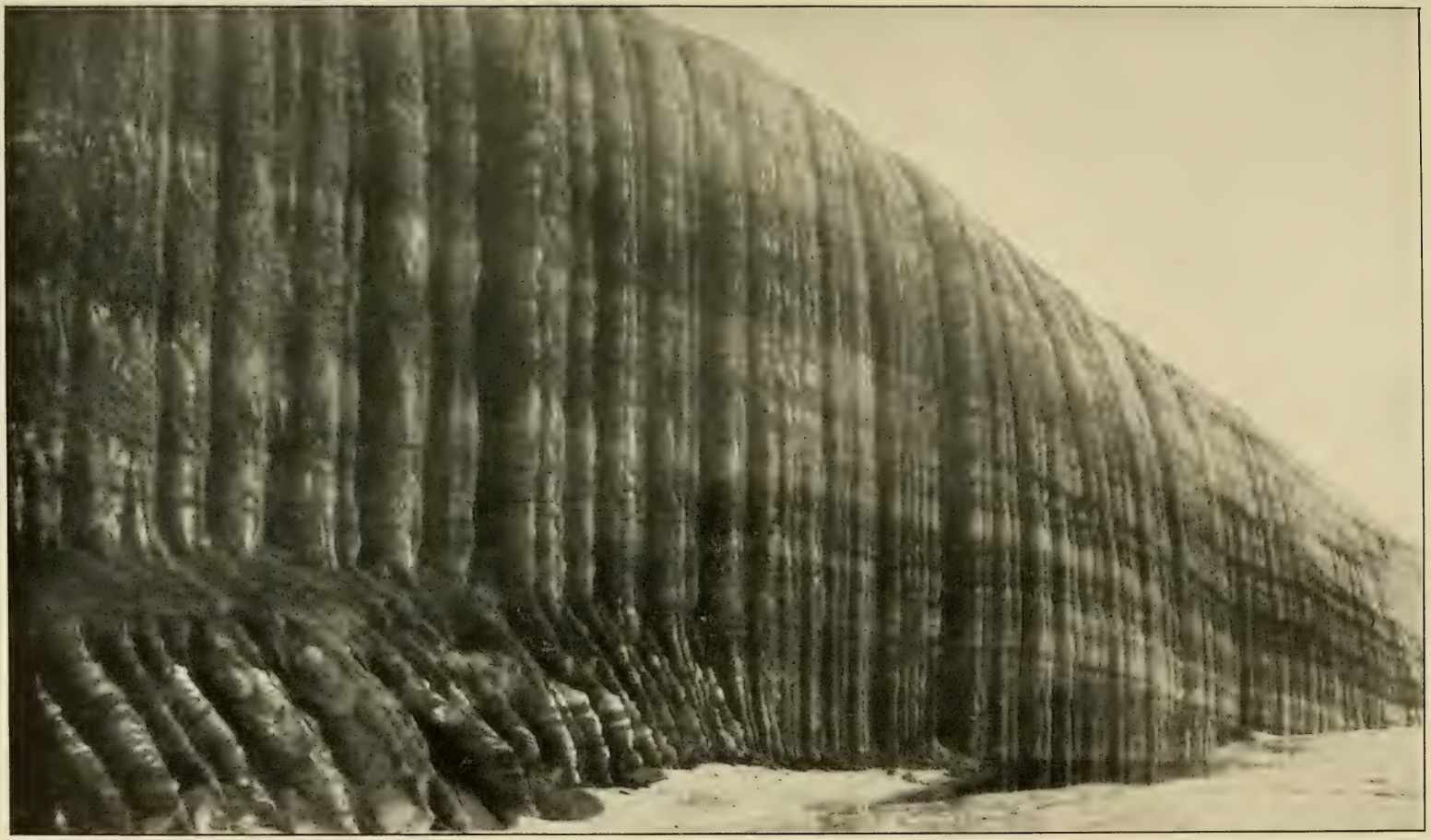


Fig. 39. Rand des Inlandeises gegenüber Jættebrinken bei *b* (siehe Kartenskizze). Wirkung des horizontalen Druckes. Mai 1908; Koch phot.

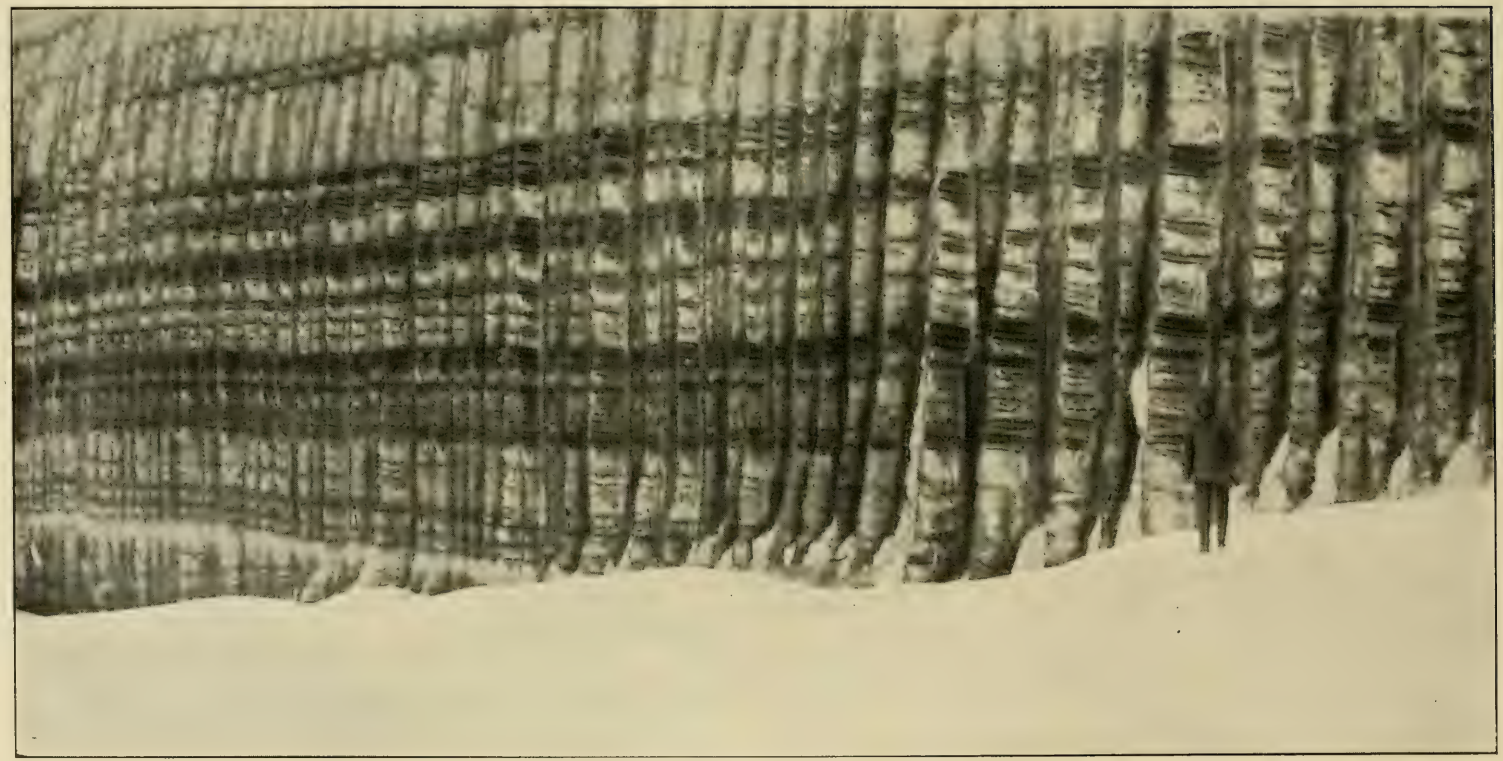


Fig. 40. Rand des Inlandeises gegenüber Jættebrinken bei *b* (siehe Kartenskizze). Wirkung des horizontalen Druckes. Mai 1908; Koch phot.

Fig. 41. Rand des Inlandeises gegenüber Jættebrinken zwischen *b* und „Hufeisenmoräne“ (siehe Kartenskizze). Mai 1908; Koch phot.

Fig. 42. Die Grundmoräne im Inlandeise bei *g* (siehe Kartenskizze). Jættebrinken, Mai 1908; Koch phot.

Fig. 43. Die Grundmoräne im Inlandeise zwischen *g* und *b* (siehe Kartenskizze) aus der Nähe gesehen. Furchen und Kanten, durch horizontalen Druck hervorgebracht. Jættebrinken, Mai 1908; Koch phot.

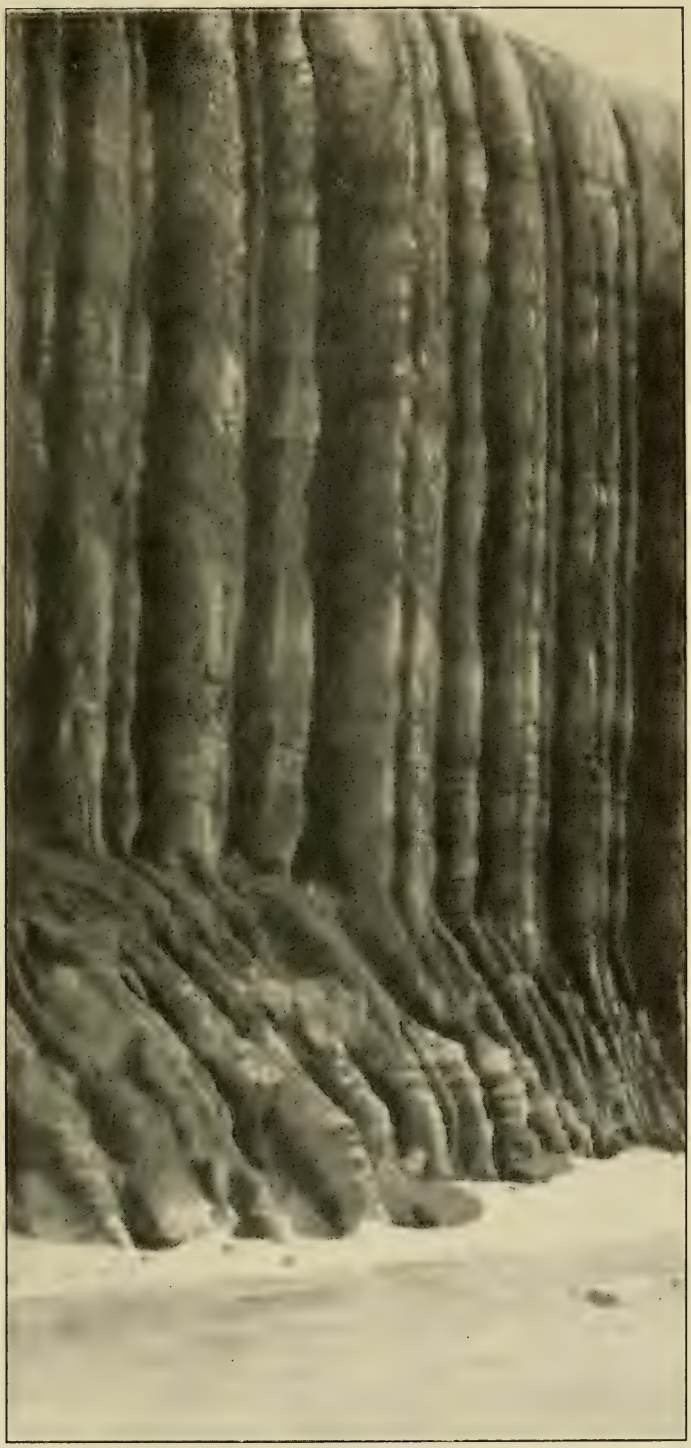


Fig. 44. Das Aussehen der Furchen und Kanten bei *b* (siehe Kartenskizze). Jættebrinken, Mai 1908; Koch phot.

Fig. 55. Zersplitterte Eiswand an der Moränenlandschaft. Im Vordergrunde Lehmhügel. Mai 1908; Koch. phot.

Fig. 56. Rand des Inlandeises an der Moränenlandschaft, stark zersplittert und mit Schmutz durchsetzt. Man beachte, dass, trotz der Zersplitterung die Schichtung erhalten ist, besonders im obersten Teil. Höhe der Eiswand ca 35 M. Mai 1908; Koch phot.

Fig. 57. Rand des Inlandeises an der Moränenlandschaft. Talus, durch Eislawinen gebildet. Starke Zersplitterung des Eises. Scherungsflächen. Höhe der Eiswand ca 40 M. Mai 1908; Koch phot.

zu bewirken. Der grösste Teil der hierdurch erzeugten Feuchtigkeit verbleibt natürlich an Ort und Stelle und gefriert wieder in der Nacht; aber etwas verdampft auch von den obersten Erdschichten, und ein geringer Teil sikkert fort an den Rändern der Schluchten, deren Abhänge dadurch mit einer Eisglasur oder einem Vorhang von Eiszapfen bekleidet werden.

In der wärmsten Jahreszeit muss dieser Teil der Moränenlandschaft einen unpassierbaren Morast bilden.

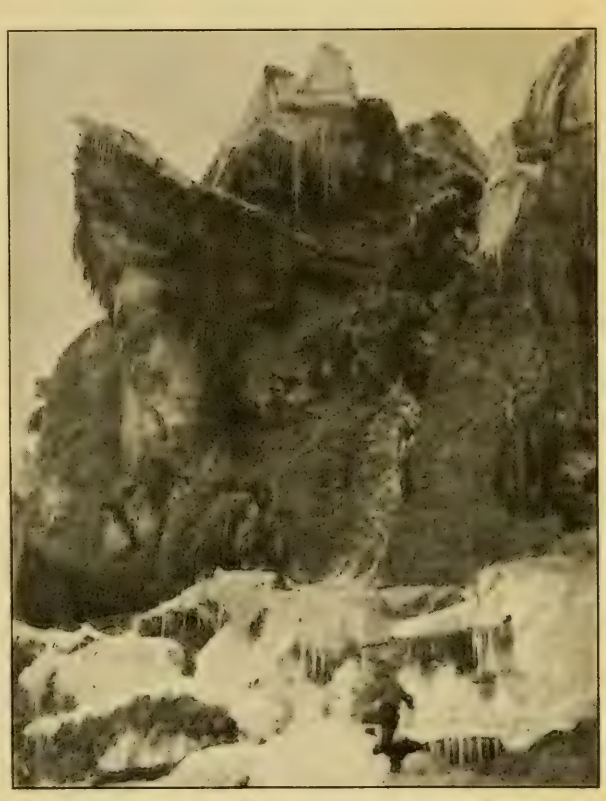


Fig. 58. Zersplitterter Rand des Inlandeises an der Moränenlandschaft. Im Vordergrunde der Talus. Mai 1908; Koch phot.

Der Umstand, dass an mehreren der Türme in ihrem obersten Teil grosse Steine beobachtet wurden, sowie dass das gröbere Geschiebe stets auf Erhöhungen angesammelt war, zeigt uns einen der Faktoren, die zur Entstehung der Landschaftsformen mitwirken. Das leichte und trockene Material wird ja stets der Forträumung durch den Wind ausgesetzt sein, wodurch die Eisoberfläche teilweise freigelegt wird, so dass die Abschmelzung fortschreiten kann; das schwere Material muss dagegen liegen bleiben und eine schützende Decke bilden.

Im östlichen Teil der Moränenlandschaft war die Abschmelzung fast vollendet. Die Oberfläche war hier stark coupiert und voll tiefer Löcher; nur an einer einzigen Stelle wurde ein 10—20 M hoher Eishügel mit abgerundeten Formen beobachtet; er war durch grosse Steine und eine dicke Lehmschicht geschützt.

Der nördliche Teil der Moränenlandschaft lag sehr tief und zeigte deutliche Spuren davon, dass er unter Wasser gewesen war, nachdem

Fig. 59. Zertrümmerung der Eisdecke eines Randsees neben der Moränenlandschaft, eine Folge der Bewegung des Inlandeises. Mai 1908; Koch phot.

Fig. 60. Zersplitterter Rand des Inlandeises an der Moränenlandschaft. Mai 1908; Koch phot.

das Eis fortgeschmolzen war. Das Material war hier stark gerollt und geglättet.

Von glacialgeologischem Interesse war auch die Beobachtung, dass über dies ganze Gebiet verstreut, ja sogar noch auf den Spitzen der höchsten Lehmtürme und- Pyramiden, sich Muschelschalen fanden. Vermutlich stehen diese Muschelfunde auch mit den an so überaus zahlreichen Stellen konstatierten Strandverschiebungen im Zusammenhang, die in der Bearbeitung der geologischen Resultate der Expedition eingehend behandelt werden.

Im südlichen Teil der Moränenlandschaft gab es einen ganz allmählichen Übergang zwischen dem „toten" Eis und dem eigentlichen Inlandeis; aber vom Abfluss des Annekssö ab nach Norden war die Grenze zwischen ihnen scharf. Das Inlandeis begann hier mit einer vertikalen Wand, die 30—40 M hoch war, und deren Fuss fast überall von einem mächtigen Talus verdeckt wurde, der durch herabgestürzte Eismassen gebildet war. Eislawinen waren hier, jedenfalls zu einer gewissen Jahreszeit, sehr häufig; am 8. Mai hörten wir 2 solche Lawinen aus einem Umkreise von 500 M um unser Zelt.

Die vertikale Eiswand, die durch die Eislawinen freigelegt wird und als ein Längsschnitt längs des Gletscherrandes aufgefasst werden kann, zeigt gewisse Eigentümlichkeiten, welche Interesse beanspruchen dürfen, namentlich wenn man sie mit den früher besprochenen Verhältnissen am Ymers-Nunatak vergleicht, wo das Eis spaltenfrei und offenbar im wesentlichen in Ruhe und einem starken horizontalen Druck ausgesetzt war. Im Gegensatz hierzu ist nämlich Kofoed-Hansens-Bræ in solchem Grade von klaffenden Transversalspalten durchsetzt, dass er vollständig unpassierbar ist, so dass man hier eher von horizontalem Zuge als von horizontalem Druck sprechen kann; und in Übereinstimmung hiermit hat die Eiswand an der Moränenlandschaft einen ganz anderen Charakter. Die Wand ist hier zertrümmert und von unzähligen kleinen Rissen durchkreuzt, die namentlich im obersten Teil des Eises alle möglichen Richtungen aufweisen, während sie in den unteren Partien vorzugsweise der Schichtung zu folgen scheinen (Fig. 57). Dass die Schichtung trotz dieser durchgreifenden Zertrümmerung des Eises dennoch selbst im obersten Teil ihren kontinuierlichen Character bewahren kann, zeigt Fig. 56.

Im nördlichen Teil der Moränenlandschaft verschwindet die Steilwand, und der Eisrand zeigt hier die wohlbekannte abgerundete, freilich überall stark zertrümmerte Oberfläche (Fig. 60).

Das verschiedene Verhalten der Eiswand bei Kap Bellevue, Jættebrinken, der Moränenlandschaft und dem Sælsö scheint gewisse Fingerzeige für das Verständnis der Mechanik des Inlandeises zu

geben. Für den Versuch einer Diskussion derselben dürften jedoch die vorliegenden Beobachtungen noch zu unvollständig sein; namentlich besitzen wir gar keine Aufschlüsse über die Temperatur und über die Strömungsgeschwindigkeit des Eises.

Messungen hierüber konnten unter den unstabilen Verhältnissen der Reisen nicht ausgeführt werden; die Bewegung des Eises ist nur am Kofoed-Hansens-Bræ und am Sælsö-Gletscher durch sekundäre Wirkungen konstatiert worden (Siehe Fig. 59 und 14).

KAPITEL IV.

Das Inlandeis von Kronprins-Christians-Land.

Im vorangehenden Kapitel ist das Inlandeis westlich vom Germania-Land, im ersten Kapitel das nördlich davon gelegene Gebiet bis ca 79½° Breite geschildert. Von hier ab bis etwa 80½° Breite tritt das Inlandeis nicht zum Meere hinaus; denn hier stellt sich ihm ein höheres, von SW nach NE verlaufendes Gebirge entgegen, welches auf diese Weise auch die hier an der Aussenküste gelegenen Sedimente vor der Abrasion durch das Eis bewahrt hat. Die Nordostspitze dieses Gebirgszuges liegt nördlich des Ingolfs-Fjordes. Von hier ab hat das Inlandeis wieder ungehinderten Zutritt zum Meere, und endigt bereits am Nordufer der Antarctic-Bugt, sowie nördlich derselben bis zur Nordost-Runding in einer kalbenden Steilwand von 10 bezw. 15 M Höhe, in derselben Weise wie die berühmte antarktische Eismauer.

Auf dieser ganzen Küstenstrecke zwischen Antarctic-Bugt und Nakkehoved (jenseits der Nordost-Runding) liegt das unebene Treibeis unmittelbar an der Küste, ohne hier für einen Streifen von ebenem, perennierendem Eise Platz zu lassen, wie es weiter südlich der Fall ist. Im Juni 1907 wurde unmittelbar südlich der Nordost-Runding längs der Küste offenes Wasser von mindestens 30 Km Breite gefunden.

Zieht man dagegen vom Nakkehoved eine Linie zur Südostecke von Peary-Land, so sind die ganzen Meeresteile im Innern dieser Grenze mit einer nie aufbrechenden Eisdecke bedeckt, welche an der Bewegung des Treibeises nicht mehr Teil nimmt. Dieser Unterschied ist bestimmend für das Verhalten des Inlandeises beim Hinaustreten auf das Meer: während es südlich der Nordost-Runding mit einer Steilwand im Meere endigt, herrschen westlich vom Nakkehoved ähnliche Verhältnisse wie in der Jökelbugt. Das Inlandeis schiebt sich hier in zusammenhängender Masse auf das Meer hinaus und flacht sich dort aus, ohne zu kalben. Hier wurden dieselben Erscheinungen getroffen wie früher in der Jökelbugt: Wogen, Spalten,

Schraubungen und spaltendurchsetzte Aufwölbungen. Die Grenze zwischen dem Inlandeise und dem Meereise war hier wegen der starken Schneebedeckung ebenso unscharf wie in der Jökelbugt. Auf dem östlichen Teil von Kronprins-Christians-Land hat das Inlandeis geradezu den Charakter eines ausgedehnten Firns; Steilwände gibt es nur da, wo das Eis in das offene Meer hinaustritt. Dagegen ist der Übergang zum eisfreien Land ein ganz allmählicher, mit sanften Abhängen, etwa wie bei Schneewehen. Zwischen der Nordost-Runding und dem Nakkehoved, wo ein ganz schmaler, eisfreier Strand vor dem Eise liegt, bildet der Eisrand allerdings einen etwas steileren Abhang, der aber doch nirgends steiler ist, als dass man mit Hundeschlitten hinauffahren könnte.

Die Dicke dieser Eiskappe ist nur gering. Ist man über den ersten östlichen Anstieg hinweg, so sieht man meilenweit über ein ganz ebenes Schneefeld weg, welches sich ausserordentlich langsam nach Westen hebt und erst in 30—50 Km Abstand eine Höhe von einigen Hundert Metern erreicht. Weit im Westen wird die einförmige Kontur des Eises durch einzelne hohe Berge unterbrochen, welche wohl östliche Ausläufer der Alexandrine-Bjerge darstellen.

Spalten, Schmelzknollen und Terrassen — die Kennzeichen der Randzone — trifft man hier nicht. Die Schneegrenze liegt am Meeresspiegel, und man befindet sich sogleich auf dem Hocheise, sobald man den äussersten Randabhang passiert hat.

Dass dies auf den ersten Anblick völlig ruhende Eis dennoch in Bewegung ist, zeigt sich nicht allein in den früher berührten Verhältnissen westlich vom Nakkehoved und bei der Eismauer südlich der Nordost-Runding mit ihrer freilich unbedeutenden Produktion kleiner Eisberge, sondern auch in dem Auftreten von Moränen. Auf dem äussersten Eisabhange an der Nordost-Runding selber traf man in 30—60 M über dem Fuss des Eises mehrere langgestreckte Haufen von lehmartiger Konsistenz, mit der Längsrichtung parallel dem Eisrande, welche Muschelschalen enthielten. Diese Moränenmassen scheinen von derselben Art zu sein, wie diejenigen, welche aus Westgrönland beschrieben sind in: Salisbury, Salient Points concerning the Glacial Geology of North Greenland. The Journal of Geology, 1896, p. 796.

Salisbury schreibt hier über Oberflächenmoränen, die parallel mit dem Eisrande verlaufen:

„Each one of these belts of drift is irregular, here higher, there lower, so that each belt, instead of being a continuous and even-crested ridge of drift, is really a succession of mounds".

An der Nordost-Runding konnte man freilich nicht von „a succession of mounds" sprechen, sondern nur von einzelnen langge-

streckten Haufen, von denen man nicht sagen konnte, dass sie Reihen bildeten.

Über die von Mylius-Erichsen auf seinem verhängnisvollen Zuge bereisten grossen Fjorde lässt sich nur wenig aussagen. Die Küsten des Danmarks-Fjordes scheinen frei von Inlandeis zu sein. Vom innersten Ende aus ist aber das Inlandeis nicht mehr weit entfernt. Die „Valdemar-Glückstadts-Land" getaufte Halbinsel ist ebenfalls frei von Eisbedeckung, dagegen wird das Ende von Hagens-Fjord durch einen Arm des Inlandeises gebildet, der hier herabsteigt.

Dass der Danmarks-Fjord und der äussere Teil des Independence-Sundes nicht etwa mit schwimmendem Inlandeis, sondern gewöhnlichem Fjordeise erfüllt ist, kann als sicher gelten. Hagen hat auf seinen Kartenskizzen einen Eisberg in der Mündung von Hagens-Fjord eingezeichnet, und die eskimoischen Zeltringe am Kap Peter-Henrik sowie die Fleischdepots am Kap Holbæk weisen bestimmt darauf hin, dass sich hier im Sommer etwas offenes Wasser bildet, ebenso wie die Bemerkung in Brönlunds Tagebuch, dass bei Kap Peter-Henrik ein Seehund gesehen wurde. Dagegen ist es keineswegs undenkbar, dass man weiter westlich im Peary-Kanal, wo der Academy-Gletscher und andere bedeutende Eisströme herauskommen, wieder auf schwimmendes Inlandeis stossen wird.

Peary-Land scheint nach den bisherigen Beobachtungen von Peary und Koch frei von einer umfangreicheren Inlandeisbedeckung zu sein, wenn sich auch an mehreren Stellen bedeutende Firnfelder vorfinden (siehe Karte 1 : 1000000, nördliches Blatt).

KAPITEL V.

Lokale Gletscher und Firngebiete.

Das vom Inlandeise freigelassene Vorland ist noch vielfach mit lokalen Firnen bedeckt, die nicht mit dem Inlandeise in Zusammenhang stehen. Von diesen Firnen stammen eine Reihe von kleineren Gletschern, die den Typus gewöhnlicher Gebirgsgletscher haben und nicht immer zum Meere hinabführen, sondern bisweilen schon mit gewöhnlichen Gletscherzungen auf dem Lande endigen. Hierher gehören auch die zahlreichen Schneewehengletscher, die sich vermutlich überall an der Ostküste Grönlands finden, besonders typisch aber auf dem Germania-Land in der Nähe der Winterstation auftraten und hier zu interessanten Höhlenbildungen Anlass gaben. Sie sollen später ausführlicher behandelt werden. Hier sei nur kurz zusammengestellt, was über die lokalen Firngebiete mit Ausschluss der Schneewehengletscher zu sagen ist.

Betrachtet man die Seehöhe, in welcher diese lokalen Firnkuppen auf dem Vorlande zu finden sind, so erkennt man deutlich das Gesetz, dass die Schneegrenze von der Küste nach dem Innern des Landes zu steigt. Am niedrigsten ist sie auf den die Aussenküste bildenden Inseln: Ile-de-France ist mit einem Firn bedeckt, der im nördlichen Teil bis zum Meer hinabreicht und nach Süden nur den Küstenabhang frei lässt, und dessen grösste Höhe über dem Meere 200 M beträgt. Auch auf Norske-Ø herrschen ähnliche Verhältnisse.

Auf dem nördlichsten Teil der Germania-Halbinsel liegt ein Firn, der einen kleinen Gletscher nach W in den Skærfjord hinabsendet. Die Firngrenze liegt hier vielleicht bei 300 M, auf dem südlichen Rücken 500 M, und die grösste Erhebung beträgt ca 600 M. Je mehr wir uns von hier dem Inlandeise nähern, desto höher rückt die Firngrenze hinauf: westlich des eben genannten liegt ein weiterer lokaler Firn zwischen Annekssö und Skærfjord, mit der Firngrenze bei ca 700 M. Von diesem Firn steigen mehrere Gletscher in das Tal nach E hinab, und ebenso ein solcher nach W zum Annekssö, wo er ca 30 M über dem See endigt (Fig. 61).

Ein weiterer Firn liegt noch nördlich des Skærfjordes, doch ist nichts näheres über ihn bekannt.

Endlich haben wir noch dicht vor dem Rande des Inlandeises auf dem Plateau zwischen Sælsö und Mörkefjord einen Firn, dessen Seehöhe 7—800 M beträgt. Es ist sehr charakteristisch, dass dieses Gebiet noch oberhalb der Firngrenze liegt, während das dahinterliegende Inlandeis, das, wie früher ausgeführt, nirgends oberhalb 400 M Höhe liegt, zur „Randzone" gehört und also überall unterhalb der Firngrenze bleibt. Letztere dürfte auf dem Inlandeise erst etwa

Fig. 61. Lokalgletscher am Annekssö. März 1908; Lindhard phot.

auf dem Meridian von Ymers-Nunatak in einer Seehöhe von 900—1000 M zu suchen sein.

Aus den nördlicheren Teilen der Küste, die nur mit Hundeschlitten bereist wurden, sind die Beobachtungen sehr unvollständig. Lamberts-Land ist mit einem lokalen Firn bedeckt, desgleichen Hovgaards-Ø. Bei letzterer reicht der Firn im Osten streckenweise bis zum Meere hinab, während er nach Westen 2 Gletscher in den Dijmphna-Sund entsendet. Auch Lynn-Ø muss einen kleinen Firn tragen, wenngleich ein solcher von unten nicht zu sehen war, denn an ihrer Nordwest-Ecke steigt ein Gletscher steil ins Meer hinab.

An der gegenüberliegenden Felswand sind 6 kleine, in regelmässigen Abständen angeordnete Gletscher sichtbar, von denen nur der südlichste nicht bis zum Meer hinabreicht. Dem gemeinsamen Firn-

gebiet dieser Gruppe dürfte auch der etwas grössere Gletscher entstammen, welcher an der Nordwand des von hier weiter nach Westen

Fig. 62. Typischer Gletscher in Ardencaple-Inlet Mai 1908; Jarner phot.

ins Land hineinführenden unbekannten Fjordarmes in schönen Eiskaskaden herabsteigt. Auch die Holms-Land benannte Halbinsel

Fig. 63. Lokalgletscher in Ardencaple-Inlet. Mai 1908; Jarner phot.

ist grösstenteils von Firn bedeckt. Von hier entspringt ein nach dem Ingolfs-Fjord abfliessender Gletscher, der aber endigt, bevor er das

Meer erreicht. Ebenso steigt eine recht bedeutende Gletscherzunge zur Aussenküste herab, endigt jedoch wenige Hundert Meter bevor sie das Meer erreicht. Anscheinend stammen von demselben Firngebiete auch zwei kleine, am Mallemukfjeld kalbende Gletscher.

In der Nordwest-Ecke des Ingolfs-Fjordes liegen zwei grosse, sehr prächtige Gletscher, von denen namentlich der nördliche zahlreiche Kalbeisstücke absondert, während sein südlicher Nachbar durch ein paar sehr markante Mittelmoränen ausgezeichnet ist. Beide scheinen bereits vom Inlandeise herzukommen, das hier an dem immer schmaler werdenden Nordende des Gebirges bereits eine Passage durch dasselbe findet, um nördlich davon wieder ganz ungehindert das Küstenland zu überfluten und bis zum Meere vorzudringen.

Zu erwähnen ist noch, dass bedeutende Firnstrecken auch die Gebirge südlich vom Teufelkap und westlich von Soranerbræ decken. Grössere Strecken von Dronning-Louises-Land scheinen gleichfalls vereist zu sein.

KAPITEL VI.

Die Schneewehengletscher auf Germania-Land.

Wenn im September der wieder einsetzende Frost der Schneeschmelze ein Ende gemacht hat, und noch kein Neuschnee gefallen ist, sieht man auf Germania-Land in grosser Zahl vereiste Reste von Schneeanhäufungen, die der kurze Sommer nicht ganz zu beseitigen vermochte. Im Herbst 1907 gab die Durchsichtigkeit dieser Eismassen verbunden mit einem starken Schmutzgehalt denselben eine

Fig. 64. Vereiste Reste von Schneeanhäufungen. September 1907; Wegener phot.

so dunkle Färbung, dass man sie aus der Entfernung eher für Felsen als für Eis ansprechen konnte. Ihre Oberfläche war ganz fein gewellt, aber so glatt, dass es auch bei mässiger Neigung schwer war, auf ihr festen Fuss zu fassen.

Diese Eismassen füllen im allgemeinen die schwachen Talsenkungen aus, die sich in dem stark moutonnierten Gelände von Germania-Land befinden. Doch nicht alle Senkungen sind in dieser Weise ausgefüllt, sondern nur diejenigen, welche bei dem vorherr-

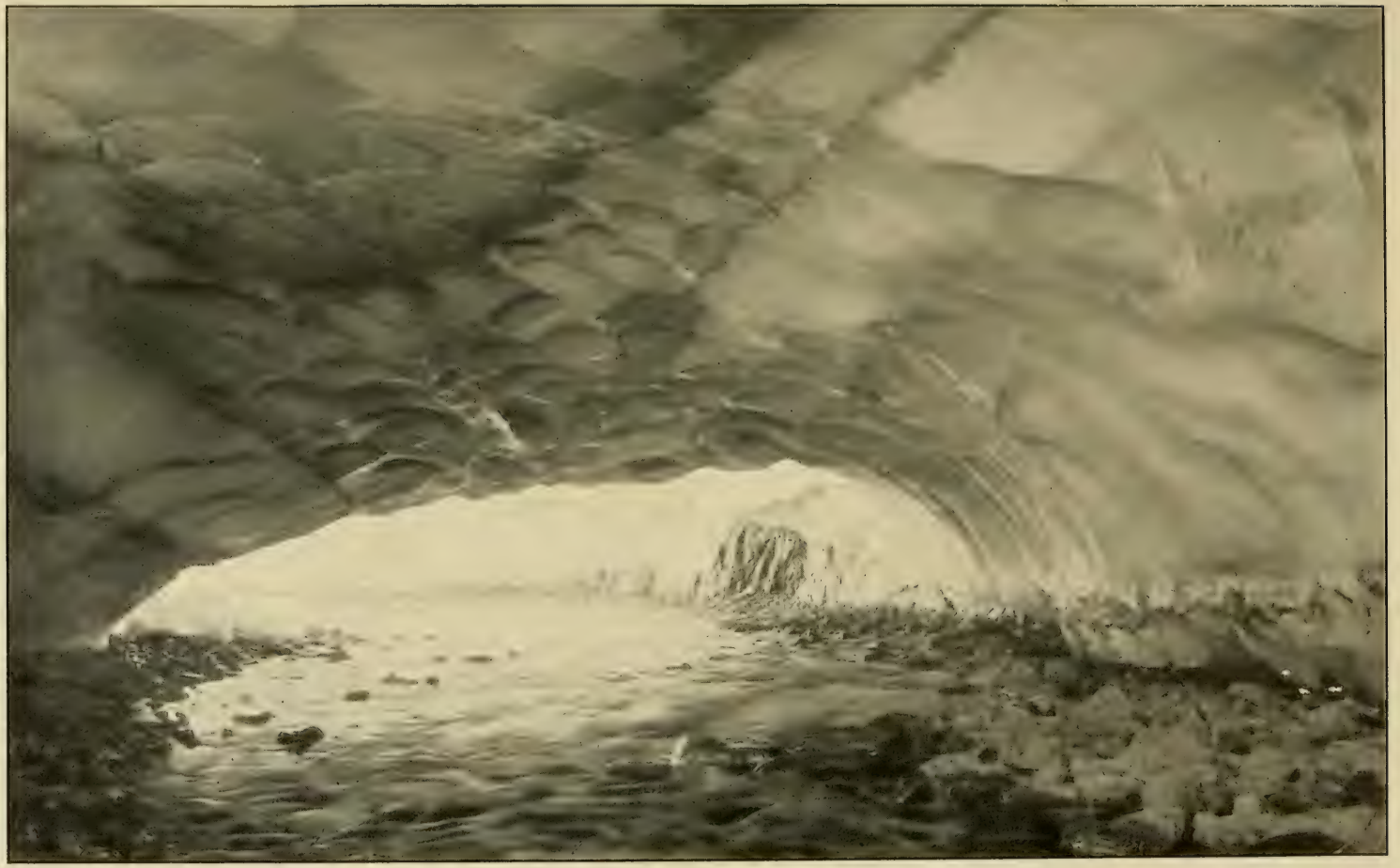


Fig. 65. Kleine Höhle oberhalb der Gnipa-Höhle. August 1907; Koch phot.

schenden Nordwestwind zu Anhäufungen von Treibschnee Veranlassung geben. Wir haben es hier mit echten Schneewehengletschern zu tun, die ihre Existenz nicht dem Niederschlag in meteorologischem Sinne, sondern nur einer gewaltigen lokalen Anhäufung des bei den Stürmen mitfliessenden Schnees verdanken. Die folgenden Zahlen mögen dies erläutern: Der Jahresniederschlag am Danmarks-Havn beträgt im Mittel aus den beiden Beobachtungsjahren 146 Mm [1]). Auf der Oberfläche des die „Gnipa-Höhle" bergenden Schneewehengletschers wurde im Frühjahr 1908 die Höhe der neuen Schneedecke gemessen. Da im Winterhalbjahr $^4/_5$ des Gesamtniederschlags fällt, gibt diese eine Messung bereits ein gutes Bild des Jahresniederschlags. Der Zuwachs im Winter 1907—08 betrug hier 1552 Mm (3.61 M Schnee von der specifischen Dichte 0.43), also mehr als das 10 fache des an der Station gemessenen normalen Niederschlags! Wie lokal diese Ablagerung von Treibschnee ist, erhellt daraus, dass nur 20 M von der Stelle entfernt, wo die 1552 Mm gemessen wurden, der winterliche Niederschlag 0 war, hier lag der Erdboden völlig schneefrei zu Tage!

Diese Verhältnisse bewirken, dass die Schneewehengletscher sich ganz unabhängig von der Seehöhe im Gelände ansiedeln. Der Begriff der Schneegrenze ist auf sie nicht anwendbar. Streng genommen schliesst ja die Kontur eines jeden derartigen Schneewehengletschers ein Gebiet ein, das oberhalb der Schneegrenze liegt, aber diese Gebiete liegen stets tiefer als ihre schneefreie Umgebung. Bei der Besprechung der lokalen Firngebiete war darauf hingewiesen, dass die Seehöhe ihrer Ränder, oder die Schneegrenze, von Osten nach Westen zunimmt, etwa von 0 bei den äussersten Inseln auf 1000 M am Dronning-Louises-Land. Auf Germania-Land liegt diese Schneegrenze etwa bei 300 bis 500 M. Die Schneewehengletscher, die hier besonders häufig sind, liegen fast alle unterhalb dieser Höhe bis zum Meere hinab an Stellen, die lediglich nach dem topographischen Relief ohne Rücksicht auf die Seehöhe ausgewählt sind. Übrigens sei in Bezug auf die Schneegrenze noch auf folgende klimatische Eigentümlichkeit aufmerksam gemacht: Für die Einstellung der Schneegrenze auf eine bestimmte Seehöhe ist offenbar die Abnahme der Temperatur mit der Höhe ein wichtiger Faktor. Nun haben aber die Drachen- und Fesselballonaufstiege am Danmarks-Havn gezeigt, dass die Temperatur bis zu einer Höhe von 2—300 M überhaupt nicht abnimmt, sondern im Gegenteil noch etwas zunimmt, und dass erst oberhalb dieser Höhe eine schwache Abnahme der Temperatur mit der Höhe einsetzt. Die Seehöhe von Germania-Land hält sich aber meist innerhalb dieser Grenze, und es ist deshalb ersichtlich,

[1]) Mittel aus 143.6 und 147.4 Mm. (vergl. Meteorologische Terminbeobachtungen am Danmarks-Havn, Danmark-Exp. II, No. 4, S. 341.

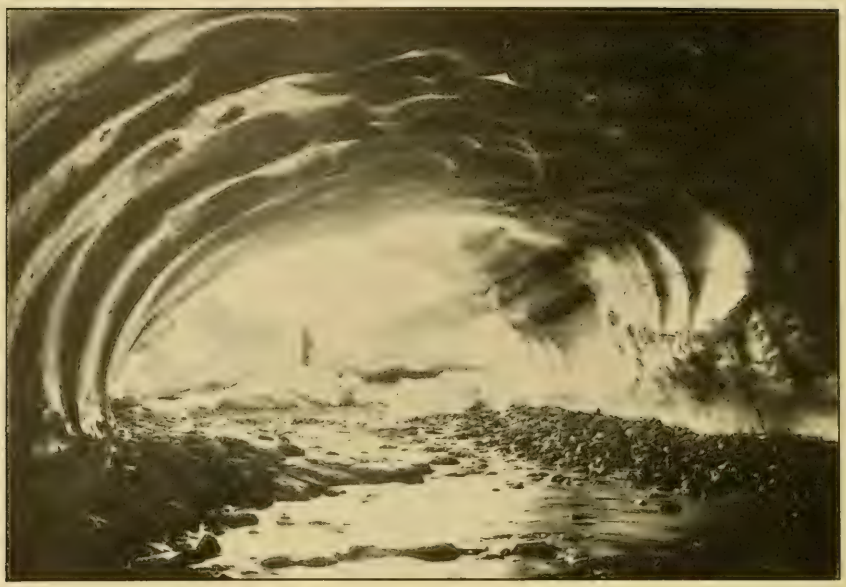


Fig. 66. Kleine Höhle oberhalb der Gnipa-Höhle. August 1907; Wegener phot.

Fig. 67. Bachbett in einem Schneewehengletscher.

dass hier die Temperaturabnahme mit der Höhe nicht mehr dazu beitragen kann, die Schneegrenze auf eine bestimmte Seehöhe einzustellen. Dieser Faktor kann erst in grösseren Höhen, zwischen 500 und 1000 M, wieder in dem angegebenen Sinne wirken.

Ein zweiter Faktor, der eine Einstellung der Schneegrenze auf eine bestimmte Seehöhe begünstigen würde, könnte in dem Umstande gesucht werden, dass die Niederschlagsmenge mit grösserer Erhebung des Erdbodens wächst. Diese Zunahme ist auch für Grönland wahrscheinlich, wenn auch nicht nachgewiesen. Aber bei so geringen Höhen, wie sie auf Germania-Land vorkommen, dürfte dieser Einfluss sehr gering bleiben. Hier haben daher diese — um so zu sagen

Fig. 68. Bachbett in einem Schneewehengletscher; Wegener phot.

— ordnenden Einflüsse fast ganz das Feld geräumt gegenüber der zufälligen lokalen Verteilung der Niederschläge durch den Wind.

Die Unabhängigkeit der Schneewehengletscher von der Seehöhe ist die Ursache von eigentümlichen Höhlenbildungen, wie sie — soweit bekannt — in dieser Weise bisher in anderen Gebieten der Erde nicht beobachtet sind. Es wird unter den geschilderten Verhältnissen offenbar häufig vorkommen müssen, dass eine Talsenke, die von einem Bach durchflossen wird, auf verschiedenen, ganz beliebigen Strecken von solchen Gletschern erfüllt wird, nämlich überall da, wo die lokalen Verhältnisse Anlass zur Ansammlung von Treibschnee geben. Der Bach fliesst dann von oben in den Gletscher hinein und unter demselben hindurch, ja er kann auf seinem Wege der Reihe nach eine beliebige Anzahl derartiger Schneewehengletscher passieren. Die auf

diese Weise gebildeten Höhlen unterscheiden sich sehr wesentlich von den bekannten Gletscherhöhlen, die von dem Gletschertor aus eine kleinere oder grössere Strecke weit unter dem Gletscher zu verfolgen sind. Diese letzteren Höhlen sind durch die Schmelzwässer des Gletschers selber gebildet, die sich unter ihm zu einem Bach gesammelt haben. In unserem Falle dagegen erstreckt sich die Höhle durch den ganzen Gletscher hindurch, und die ausserordentlich regelmässigen Formen derselben sind nicht mehr dem Wasser des Baches, sondern der Luftschmelzung und Verdampfung zuzuschreiben.

Fig. 69. Kleine Höhle oberhalb der Gnipa-Höhle. August 1907; Koch phot.

Die grösste derartige Höhle soll im folgenden Kapitel eingehend beschrieben werden. Sie lag nur etwa 1 Stunde vom Winterhafen entfernt. Dass es sich bei diesen Höhlenbildungen nicht um ein vereinzeltes Curiosum handelt, sondern um eine typische Erscheinung, die durch die eigentümlichen klimatischen Verhältnisse bedingt ist, geht aus der grossen Anzahl hervor, welche allein auf dem Germania-Land gefunden wurde. Ausser der genannten Gnipa-Höhle wurde etwas weiter oben an demselben Bache ein zweiter aber kleinerer Schneewehengletscher gefunden, der gleichfalls zu Höhlenbildungen kleineren Massstabes Anlass gibt.

Bei Kap Bismarck liegt unmittelbar an der Küste ein Schneewehengletscher, unter dem der Abfluss eines Sees durch eine Höhle

hindurch zum Meere hinaustritt. Eine besondere Eigentümlichkeit besteht hier darin, dass die Oberfläche dieses Sees nur etwa 1 M über

Fig. 70. Perennierende Schneewehe mit Eishöhle bei Syttenkilometernæsset. Der sehr kleine Eingang der Höhle ist ganz unten vorn in der Schneewehe zu sehen. August 1907; B. Thostrup phot.

dem Meere liegt, so dass bei Flut umgekehrt das Meerwasser in den See hinein- und also durch die Höhle hindurchfliesst.

Eine dritte derartige Höhle wurde bei Gelegenheit der Messtisch-

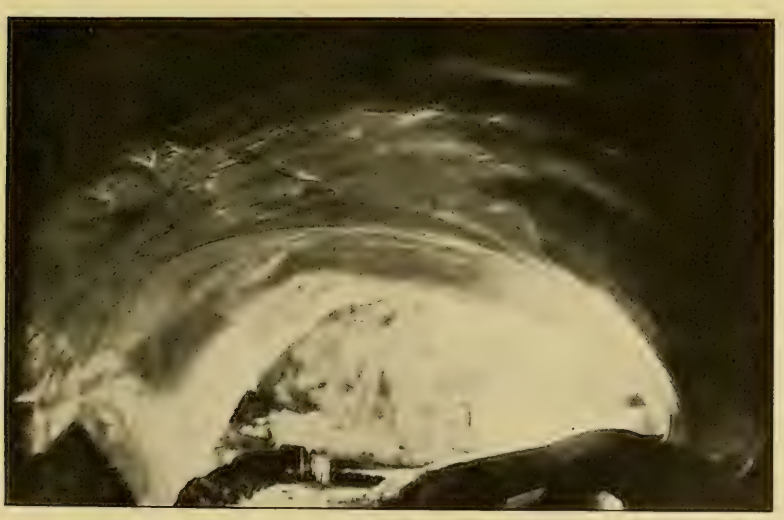


Fig. 71. Eishöhle bei Syttenkilometernæsset. August 1907; B. Thostrup phot.

arbeiten nahe der Ostküste von Germania-Land gefunden und auch photographiert (Fig. 70 und 71).

Eine 4. und 5. wurde noch weiter nördlich auf Germania-Land entdeckt; auch auf der Hvalslette östlich vom Lakseelv wurden zwei

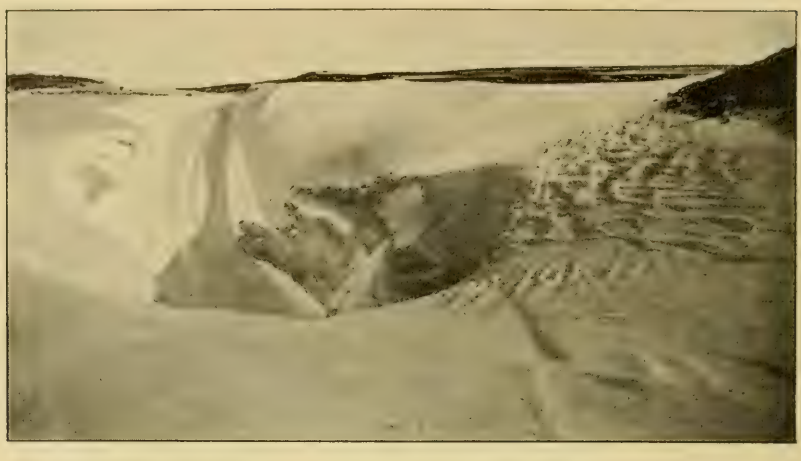


Fig. 72. Höhlentrichter auf Store-Koldewey. Mai 1907; Jarner phot.

Fig. 73. Schmelzwasserbach auf dem Gnipa-Höhlen-Gletscher. August 1907; Wegener phot.

freilich nur kleine Höhlen gefunden, und auch auf Store-Koldewey (Fig. 72) sowie nördlich von Kap Amélie trafen wir solche Eishöhlen.

Endlich sei erwähnt, dass auch auf Peary-Land im Mai 1907 ein „Einsturztrichter" gesehen wurde, wie er sich am unteren Ende einer solchen Höhle zu bilden pflegt. Die Höhle selbst konnte leider nicht besucht werden. Gerade Peary-Land dürfte mit seiner geringen Inlandeisbedeckung und der daraus folgenden Möglichkeit langer Bachläufe ähnlich wie Germania-Land reich an solchen Höhlen sein, die allerdings bei einem flüchtigen Besuch des Landes meist unbemerkt bleiben. Wurde doch auch die Gnipa-Höhle erst nach mehr als einjährigem Aufenthalt der Expedition am Winterquartier entdeckt.

Schliesslich sei der Neuheit des Phänomens wegen hinzugefügt, dass I. P. Koch bereits im Jahre 1900 2 derartige Eis-Höhlen im Flemming-Inlet (nördlich von Scoresby-Sund) bemerkt, und die eine derselben, die etwa 100 M lang war, durchgangen hat.

Es sei gleich an dieser Stelle noch einer besonderen Erscheinung gedacht, die wiederholt auf der Oberfläche der Schneewehengletscher bemerkt wurde, nämlich der kleinen Schmelzwasserbäche von überraschend regelmässigem Lauf. Die nebenstehende Abbildung zeigt einen solchen Bach auf der Oberfläche des Gnipa-Höhlen-Gletschers. Die Breite des Wasserstreifens beträgt nur etwa $^1/_2$ M. Schon dem blossen Augenscheine nach besitzt das Wasser eine sehr schnelle Bewegung, und dies mag wesentlich dazu beitragen, dem Bett eine so überraschend regelmässige Form zu geben. Eine Messung der Geschwindigkeit konnte leider nicht ausgeführt werden. An einer Stelle aber, wo ein spitzer Stein im Grunde festgefroren war, wurde das Wasser durch dies Hindernis in einem Strahl von ca 1 M Höhe in die Luft gejagt. Derartige kleine Oberflächenbäche wurden auf den meisten Schneewehengletschern getroffen, und stets waren die regelmässigen Windungen und die grosse Geschwindigkeit des Wassers auffallend.

KAPITEL VII.

Die Gnipa-Höhle.

Etwa 1 Stunde nördlich des Danmarks-Havn liegt ein Schneewehengletscher, in welchen 2 Bäche an verschiedenen Stellen hineinfliessen (siehe Karte der Gnipa-Höhle). Sie vereinigen sich unter dem Gletscher und setzen hier gemeinsam ihren Weg fort, auf diese Weise eine mehr als 800 M lange, in der oberen Hälfte gegabelte Höhle bildend. Über die Dimensionen der Höhle, sowie die Mächtigkeit des über ihr liegenden Gletschereises geben die (im Herbst 1907 aufgenommenen) Quer- und Längsschnitte Aufschluss.

Fig. 74. Der Schneewehengletscher der Gnipa-Höhle. September 1907; B. Thostrup phot.

Zur Zeit der Entdeckung dieser Höhle, Mitte August 1907, war der sie erfüllende Bach noch so wasserreich, dass er dem Eindringen Schwierigkeiten bereitete. Allein sein Wasserreichtum nahm mit jedem Tage ab, so dass schon bald darauf eine Expedition mit Hülfe einer Laterne auf den an der Seite des Baches frei liegenden Steinen durch die ganze Höhle hindurch unternommen werden konnte. Die Hauptarbeiten wurden hier aber erst im September und Oktober ausgeführt, nachdem der Bach völlig versiegt, und seine letzten Reste

Fig. 75. Eingang zur Gnipa-Höhle. September 1907; Lindhard phot.

Fig. 76. Mit verzweigten Eiszapfen geschmückter Eingang zur Gnipa-Höhle. September 1907; Lindhard phot.

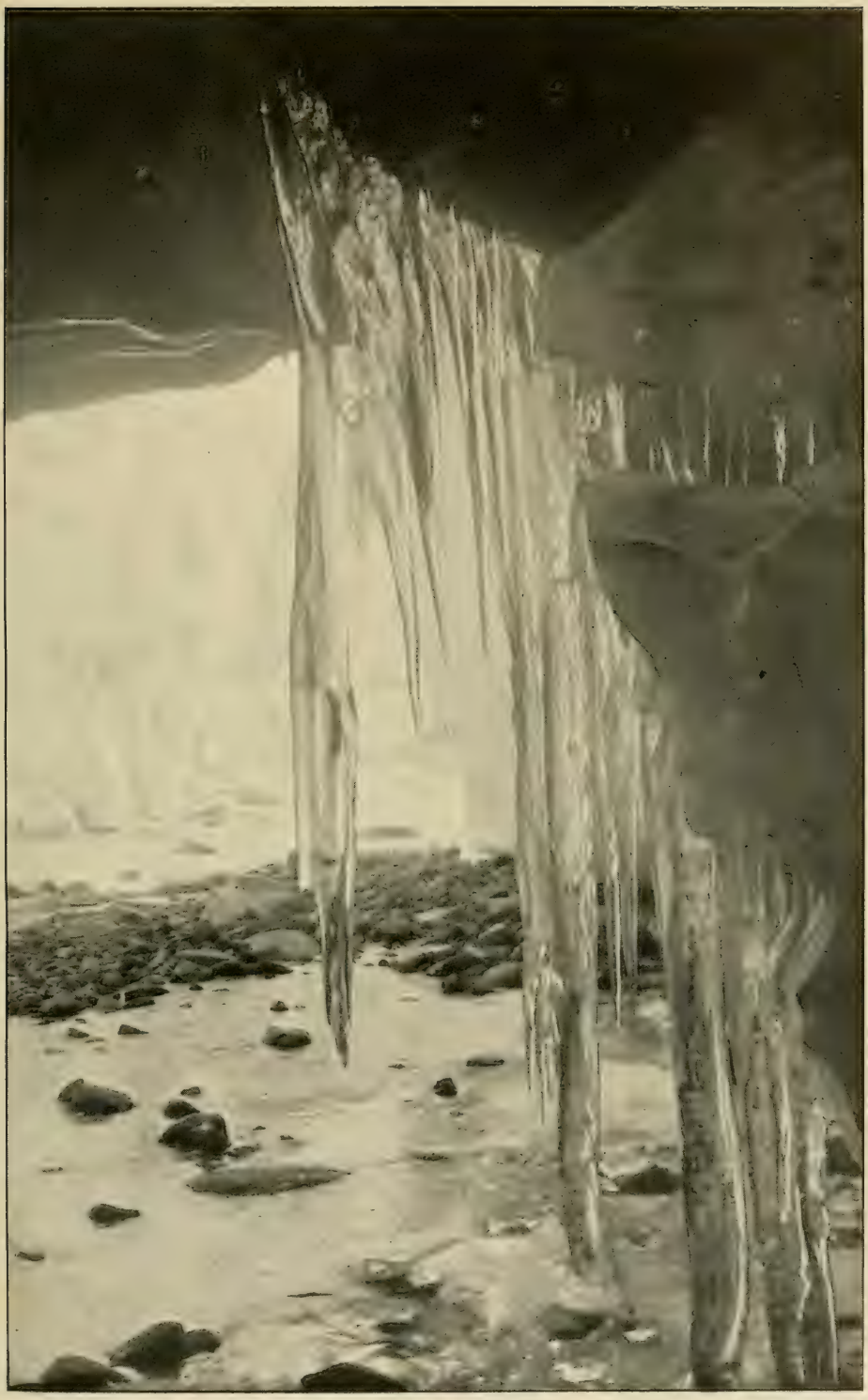


Fig. 77. Verzweigung von Eiszapfen am Eingang zur Gnipa-Höhle. September 1907; Koch phot.

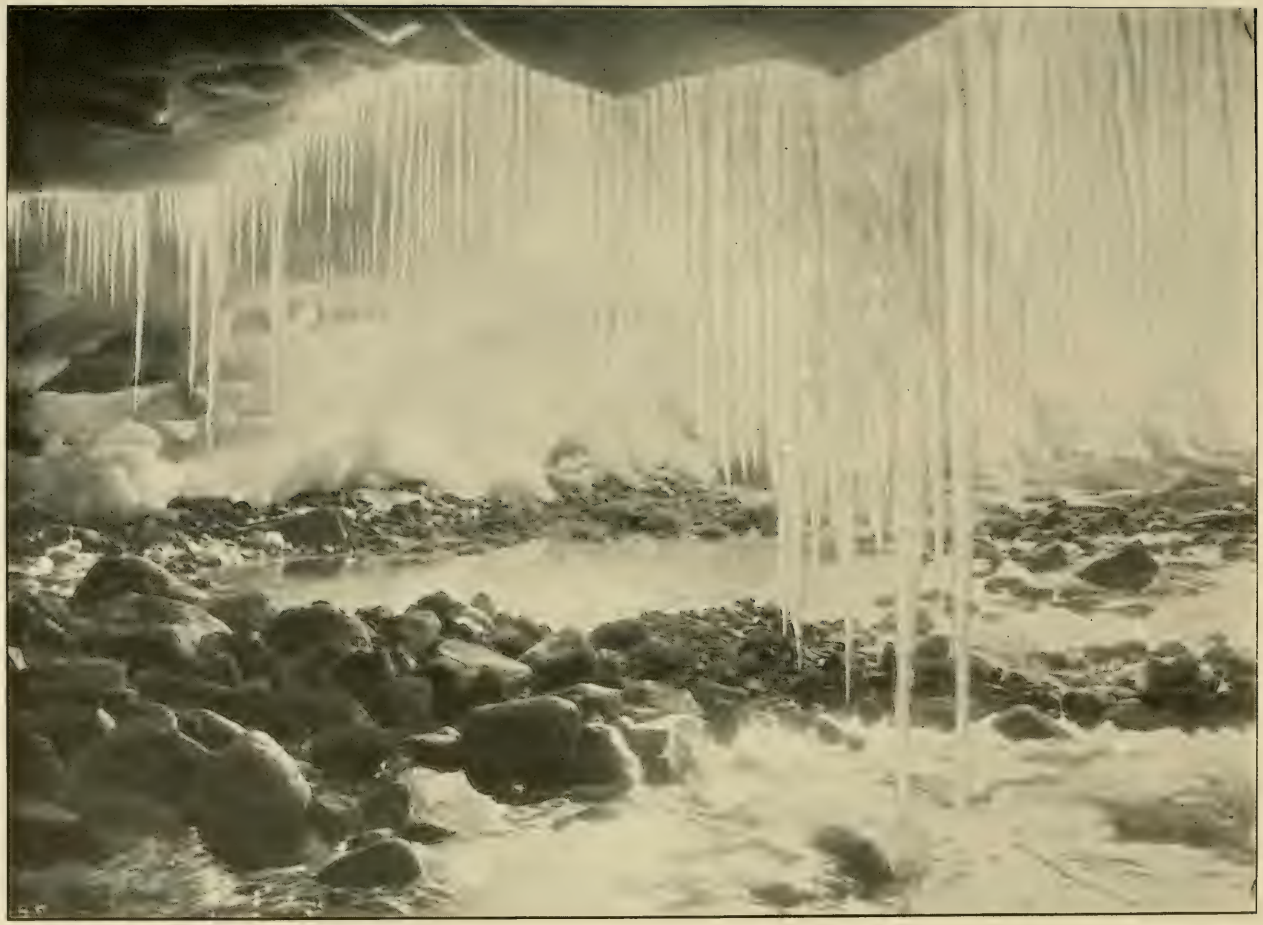


Fig. 78. Eiszapfen mit gekörnter Oberfläche am Eingang zur Gnipa-Höhle. September 1907; Koch phot.

Fig. 79. Vom Innern der Gnipa-Höhle. Im Vordergrunde links Eiszapfendraperien; im Mittelgrunde Eis-Stalaktit und Eis-Stalagmit. Links hinter der Zapfendraperie ist der untere Eingang der Höhle zu sehen. September 1907; Wegener phot.

Fig. 80. Vom Innern der Gnipa-Höhle. Im Vordergrunde der Eis-Stalagmit (Tropfeis). September 1907. Wegener phot.

Fig. 81. Unteres Ende der Gnipa-Höhle vor Gefrieren des Baches. Erster Anfang der Eiszapfenbildung. (Vergl. Fig. 81). September 1907; Lindhard phot.

Fig. 82. Unteres Ende der Gnipa-Höhle nach Gefrieren des Baches und Ausbildung der Eiszapfen (Vergl. Fig. 81). September 1907; Wegener phot.

Fig. 83. Der regelmässige mittelste Teil der Gnipa-Höhle. Auskeilende und intermittierende Schichtung. Magnesiumaufnahme (die Lichtquelle befindet sich hinter dem Felsen links). September 1907; Wegener phot.

Fig. 84. Offener Kessel im westlichen Arm der Gnipa-Höhle. September 1907; Koch phot.

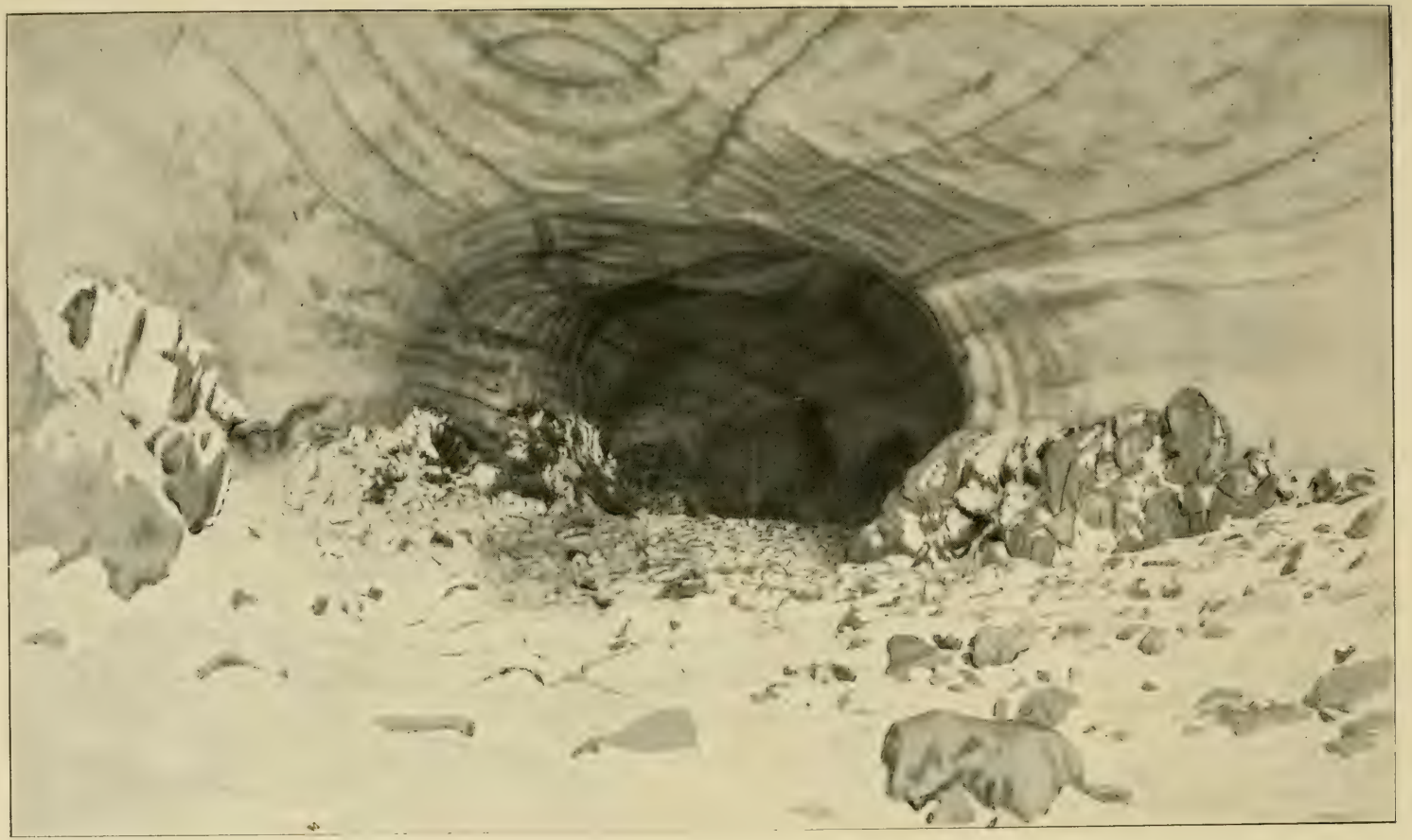


Fig. 85. Treibschnee im nördlichen Arm der Gnipa-Höhle. September 1907; Wegener phot.

Fig. 86. Nördlicher Arm der Gnipa-Höhle. Vom Hintergrunde einströmendes Tageslicht von den Eiswänden reflektiert. Durchfallendes Tageslicht durch die sehr dünne Eisdecke ganz oben im Mittelgrunde. Felsen und Bach im Vordergrunde von Magnesiumlicht beleuchtet. September 1907; Wegener phot.

Fig. 87. Vom Innern der Gnipa-Höhle; Bach noch nicht gefroren. September 1907; Wegener phot.

Fig. 88. Eisblöcke vor dem Eingang zur Gnipa-Höhle. September 1907; Wegener phot.

gefroren waren. Zu dieser Zeit wurde die Detailkarte der Höhle und des ganzen Gletschers aufgenommen, ferner eine Thermometeranlage zur Messung von Eistemperaturen gemacht, sowie eine grosse Zahl von Photographien und auch einige Ölgemälde hergestellt.

An der Hand der Photographien und der Karte sei hier eine Schilderung aller Erscheinungen gegeben, welche ein Besuch der Gnipa-Höhle zeigt.

Der untere Eingang ist schon aus grosser Entfernung durch einen Einsturz der Eismassen kenntlich. Dieser Einsturztrichter wurde von uns auch bereits im Herbst 1906 bemerkt, aber nicht näher

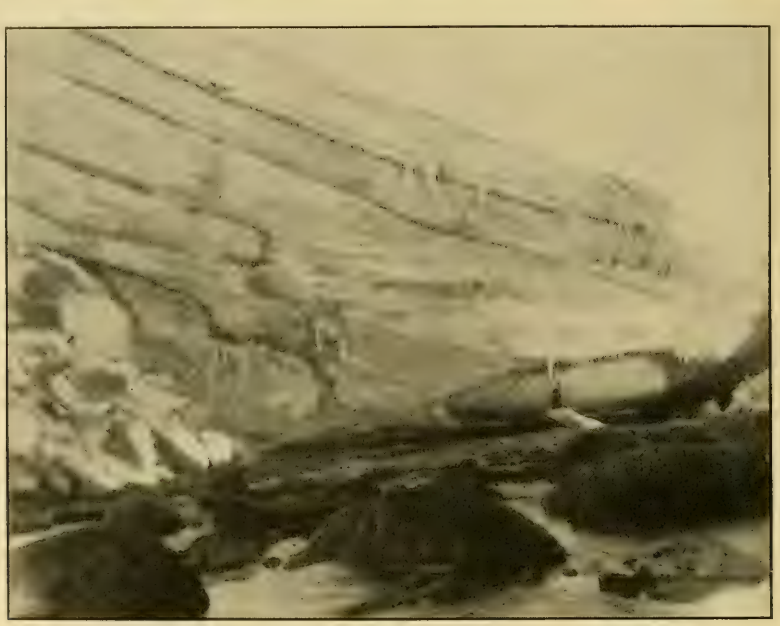


Fig. 89. Schichtung des Gnipa-Höhlen-Gletschers. September 1907; Lindhard phot.

untersucht, so dass die Höhle damals noch unentdeckt blieb. Um n die Höhle zu gelangen, muss man zunächst durch ein Gewirr von herabgestürzten Eisblöcken (Fig. 88) hindurch das Bett des Baches gewinnen, der hier eine kurze Strecke zwischen zwei senkrechten Eismauern einherströmt. Diese Schnee- oder Eiswände zeigen eine ausgesprochene Schichtung, indem dünne Schmutzschichten die sonst schneeweissen Massen horizontal durchziehen (Fig. 89). Man ist im ersten Augenblick versucht, dies als Jahresschichtung anzusprechen. Indessen lehrten uns Beobachtungen an anderen Stätten, dass man mit dieser Schlussfolgerung ausserordentlich vorsichtig sein muss. An der unserer Station nahe gelegenen Mündung des Vester-Elv, die im Herbst 1906 ganz schneefrei gewesen war, hatte sich im

Winter 1906—07 eine grössere Schneewehe gebildet, die im Sommer 1907 von dem Bache zunächst durchbrochen wurde und dann im Laufe des Sommers ganz forttaute. In dieser Schneewehe zeigte sich ebenfalls eine sehr markante Schichtung in Gestalt von Schmutzhorizonten (Fig. 90), und doch war sie vollständig das Produkt nur eines Winters! Hier war es offenbar, dass die Schichtung nur durch die verschiedenen Sturmperioden des Winters zustande gekommen war. Es ist anzunehmen, dass auch auf dem Gnipa-Höhlen-Gletscher ähnliche falsche Jahresschichtungen entstehen, und man darf daher die dortigen Schmutzhorizonte nicht ohne weiteres als Jahresschich-

Fig. 90. Schneewehe an der Mündung des Vester-Elv. Falsche Jahresschichtung. Juli 1907; Wegener phot.

tung auslegen. Auf das Verhältnis dieser Schmutzhorizonte zu der Struktur werden wir später zurückkommen.

Der eigentliche Eingang der Höhle war in der Mitte so niedrig, dass man nur gebückt hindurchgelangen konnte (Fig. 75). Sobald man aber hier hindurchgeschlüpft war, gelangte man sogleich in einen ca 8 M hohen Raum, der durch den Eingang noch genug Tageslicht empfing, um alle Einzelheiten noch deutlich erkennen zu lassen (Fig. 79—82). Dieser ganze unterste Teil des Gletschers war durch den sich hier ausbreitenden Bach so unterhöhlt, dass man überall rechts und links einen Stab mehrere Meter weit unter das Eis hinunterschieben konnte, im Gegensatz zu dem mittleren und oberen Teil der Höhle, wo die Eismassen überall dem Boden fest auflagen.

Beim Einsetzen des Frostes entstanden an diesem unteren Ausgang der Höhle allerorts die prächtigsten Eiszapfenbildungen. Die vor dem Eingange befindliche, etwas überhängende Eiswand war mit ganzen Draperien von Eiszapfen in mehreren Reihen geschmückt, und der Eingang selbst war wie mit einem Vorhang fast von den Zapfen geschlossen (Fig. 75 und 91), die sich nicht selten verzweigten (Fig. 76 und 77). Im Anfang war die Oberfläche dieser Zapfen uneben und gekörnt, so dass die Zapfen undurchsichtig erschienen (Fig. 78). Nachdem aber der Frost alles Wasser hatte erstarren lassen, und die Verdampfung eine Zeitlang gewirkt hatte, verschwanden

Fig. 91. Eiszapfen-Draperie beim Eingang zur Gnipa-Höhle, von innen. September 1907; Wegener phot.

diese Unebenheiten, die Zapfen wurden vollkommen glatt und durchsichtig wie Glas. Man kann diese Veränderung deutlich durch einen Vergleich der beiden Abbildungen No. 78 und No. 93 erkennen. Auch im Innern der Höhle bildeten sich vermöge der hier im untersten Teile noch vorhandenen Spalten und sonstiger Unregelmässigkeiten ganze Systeme von Eiszapfen. Auf der Abbildung Fig. 79 sieht man links in Vordergrund einen solchen Vorhang von Zapfen, die ganz bis zu dem spiegelglatt gefrorenen Bach hinabreichen. Von der Mitte der Decke hängt ein ca 2 M langer Komplex von Zapfen herab, dem man den Namen „Kronleuchter“ gab. Diesem Eis-Stalaktiten entspricht am Boden ein Stalagmit von eigentümlichem Aussehen, der ausserordentlich markant die für Tropfeis charakteristische traubenförmige Struktur erkennen lässt (Fig. 80). Ein besonderes Interesse bot

auch die fortschreitende Biegung der Eiszapfen, welche von der Decke des Einganges bis ganz zum Erdboden herabgewachsen waren (Fig. 92

Fig. 92. Gebogene Eiszapfen beim Eingang zur Gnipa-Höhle, von aussen. September 1907; Wegener phot.

und 93). Die Ursache für diese Biegung war eine langsame, aber stetige Senkung der Decke. Der Betrag dieser Senkung wurde nach einer primitiven Methode zu 2 verschiedenen Zeiten gemessen und ergab sich übereinstimmend zu etwa $^1/_2$ Cm pro Tag. Infolge dieser Senkung, die wohl ausserdem noch mit einer geringen Bewegung nach vorn verbunden war, bogen sich diejenigen Zapfen, die unten bereits fest am Boden angewachsen waren, ohne zu brechen, ja einige legten auf diese Weise schliesslich ihr unteres Ende horizontal auf den Boden. Die Natur lieferte uns hier eine interessante Demonstration für die Plastizität des Eises. Im Laufe der Zeit trat hier bei den Eiszapfen am Eingang der Höhle noch

Fig. 93. Gebogene Eiszapfen beim Eingang zur Gnipa-Höhle. September 1907; Wegener. phot.

eine andere Veränderung durch die Verdunstung ein. Die Verdunstung wirkte (aus nicht ganz geklärten Ursachen) erheblich mehr am oberen Ende der Zapfen als in der Mitte. Infolgedessen wurden die Zapfen in ihrem oberen Teil — obwohl dieser anfangs der dickste gewesen war — immer mehr in dünne Lamellen verwandelt, die parallel standen und der in die Höhle ein- oder aus ihr herausströmenden Luft einen möglichst freien Durchlass gewährten. Die meisten dieser Zapfen sahen wir dann später ganz abfallen, wenn ihr oberes Ende zu dünn geworden war, um die Last zu tragen. Andere Zapfen, die dem Schneetreiben ausgesetzt waren, wurden bei den ersten Schneestürmen mit einer dicken Schneekruste bedeckt (vergl. Abbildung 97) und brachen schliesslich ab, wenn das Gewicht zu schwer wurde.

Diese Eiszapfen befanden sich nur im alleruntersten Teil der Höhle, der sehr unregelmässig gebaut war und offenbar von Jahr zu Jahr grossen Veränderungen unterlag. Noch in diesem Teil, wenngleich etwas weiter innen (nur wenig unterhalb des Querschnitts *a* der Karte) wurden im Herbst 1907 mehrere Thermometer im Eise angebracht, welche die Temperatur im Innern des Eises zu messen gestatteten. Sie waren horizontal in die Seitenwand der Höhle, etwa 1 M über dem Boden, eingelassen, und zwar der Reihe nach 3—4 Cm, 1 M und 2 M tief. Die Hoffnung, die hiermit im Herbst 1907 begonnenen Beobachtungen im Frühjahr 1908 fortsetzen zu können, schlug leider fehl, da die Höhle hier so vollkommen verschüttet war, dass es nur mit äusserst umfangreichen Arbeiten möglich gewesen wäre, sich hindurchzugraben, und es wurde auf diese Weise nur eine kurze Beobachtungsreihe vom September und Oktober 1907 erhalten. Diese Messungen sind in der folgenden Tabelle wiedergegeben. Wenngleich einer so fragmentarischen Zahlenreihe nur eine sehr geringe Bedeutung beizumessen ist, so dürfte dieselbe doch die Ansicht stützen, dass die Temperatur im Innern des Schneewehengletschers im Winter sehr erheblich unter den Gefrierpunkt sinkt, dass also der im Herbst wasserdurchtränkte Gletscher vollständig starr gefriert, was bei seiner geringen Mächtigkeit ja auch in der Tat von vornherein zu erwarten ist.

Etwas oberhalb der Thermometeranlage kommt man an ein grosses rundes Gewölbe (vergl. d. Karte), dessen Boden grösstenteils mit herabgestürzten Eismassen bedeckt ist, so dass der Bach hier gezwungen ist, einen S-förmigen Bogen zu beschreiben, während gleichzeitig ein kleinerer Arm sich abzweigt, um sich ein Stück unterhalb wieder mit dem Hauptarm zu vereinigen. Auf dieser ganzen Partie fliesst der Bach auf losem Geröll und hat die Tendenz, sich auszubreiten und die Eismassen seitlich zu unterwühlen. Bis zu diesem Punkte bietet daher die Höhle viel Ähnlichkeit mit den ge-

Temperaturmessungen in der Gnipa-Höhle.

1907 Datum	Lufttemp. am Danmarks-Havn (Tagesmittel)	Lufttemp. in der Höhle	Eistemperatur in der Tiefe von 3 Cm	100 Cm	200 Cm
22. Sept.	— 2.5		— 4.8	—4.0	—2.9
23. „	— 2.5		— 4.5	—3.9	—3.8
24. „	— 4.0		— 4.0	—3.6	—3.4
25. „	— 5.3		— 3.8	—3.6	—2.8
26. „	— 6.8		— 4.6	—3.6	—3.5
29. „	— 9.1		— 4.6	—3.6	—3.6
30. „	—10.9		— 7.0	—6.0?	—5.0
1. Okt.	—11.8		— 7.0	?	—3.9
2. „	—12.8	—10.0	— 7.3	—4.6	—4.6
4. „	—11.5	— 8.5	— 7.9	—5.0	—4.0
5. „	—10.8	— 9.9	— 7.9	—5.0	—4.0
6. „	—10.1	— 7.8	— 7.7	—5.3	—4.0
8. „	—11.4	— 8.5	— 7.4	—5.4	—4.1
9. „	—11.8	— 9.9	— 7.8	—5.5	—4.6
10. „	—13.6	—11.7	— 9.0	—5.7	—4.6
12. „	—11.5	—10.9	— 8.8	—6.4	—5.0
14. „	—16.7	—14.3	—10.0	—6.7	—5.0
15. „	—20.1	—17.6	—12.0	—6.9	—5.4?
16. „	—18.1	—12.1	—11.0	—7.0	—5.1
17. „	—17.5	—12.8	—12.2	—7.2	—5.1
18. „	—16.7	—18.3	—12.3	—7.7	—6.0?
19. „	—15.3	—12.2	—11.2	—7.9	—5.1
20. „	—17 6	—11.4	—10.8	—8.2	—5.1
30. „	—18.2	—13.2	—12.0	—9.9	—6.6

wöhnlichen Gletschertoren. Von hier ab aufwärts ändert sich aber das Bild, denn nun tritt man in eine Röhre von überraschender Regelmässigkeit ein, deren Wände rechts und links dem Boden fest aufruhen (Fig. 83). Der Boden selber besteht nicht mehr aus Geröll, sondern aus fest anstehendem Gestein, und der Bach fliesst hier in einem vertieften Bett, so dass er nie oder doch nur bei excessiv hohem Wasserstande mit den Eiswänden in Berührung kommt. In diesen mittleren Teil der Höhle dringt keine Spur von Tageslicht mehr. Die Photographien sind hier mit Magnesiumlicht aufgenommen.

Besonders schön tritt hier die Schichtung des Eises hervor. Eine nähere Untersuchung zeigte, dass man hier zwischen Staubschichten und Schichten von Blaueis[1]) aus blasenarmen Eise unterscheiden muss; letztere sind es im allgemeinen, die den dunklen Streifen auf den Photographien entsprechen. Die ersteren wurden schon früher

[1]) Nicht mit der in der Gletscherliteratur viel besprochenen „Blaubänderung“ zu verwechseln.

als „falsche" Jahresschichten charakterisiert, während das Blaueis anscheinend die wahren Jahresschichten darstellt. Hiernach ist nicht zu erwarten, dass die Staubschichten eine bestimmte Lage im System des Blaueises einnehmen, und in der Tat wurden sie hier an den verschiedensten Stellen, bald über und bald unter den Blaueisschichten, bald von ihnen getrennt und bald in ihnen gefunden. Indessen schien doch eine bestimmte Anordnung besonders häufig vorzukommen, nämlich diejenige, bei welcher der Staubhorizont mit der unteren Grenze des Blaueises zusammenfällt.

Die Schichtung im Eise ist durch die nebenstehende schematische Figur 94 veranschaulicht. Ausser den beiden Hauptarten des Eises, nämlich weissem, lufterfülltem Eis und klarem, blauem Eis, kam hier und da im obersten Teil des weissen Eises noch eine dünne Schicht halbklaren Eises von schmutziger, gelbbrauner Farbe vor. Während das weisse Eis nach unten meist allmählich in das Blaueis überging,

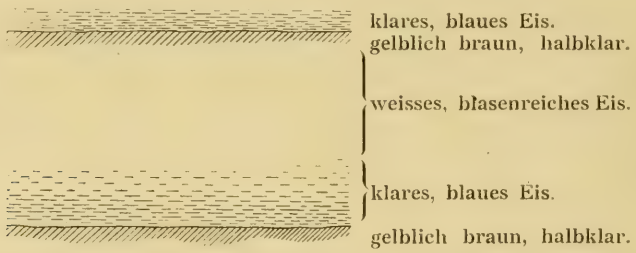


Fig. 94. Schematische Darstellung der Schichtung in den Eiswänden der Höhle.

war andererseits zwischen diesem und dem darunterliegenden weissen Eis (oder der gelbbraunen, halbklaren Schicht) eine scharfe Grenze vorhanden.

Die skizzierte Schichtung dürfte ihre Erklärung durch die folgenden Betrachtungen und Beobachtungen finden:

Im Herbst, bevor der Schneefall beginnt, besteht die Oberfläche des Firns in einer schwach gewellten, glatten Eisdecke, welche (von oben gesehen) undurchsichtig, graubraun und etwas schmutzig ist. Diese Oberfläche selber ist es, welche später im Innern des Eises die gelbbraune halbklare Schicht oberhalb des weissen Eises bildet.

Im Winter wird das Eis mit einer sehr dicken Schneeschicht bedeckt (siehe S. 57); aber im Lauf des nächsten Sommers schmilzt der Schnee von oben her fort, und das entstandene Wasser wird von dem tiefer liegenden Schnee aufgenommen, der nach und nach mit Feuchtigkeit gesättigt und zum Teil auch aufgelöst wird. Die Eisdecke des letzten Herbstes bildet indessen eine wasserdichte Schicht; weiter als bis zu dieser kann das Wasser nicht eindringen; es folgt

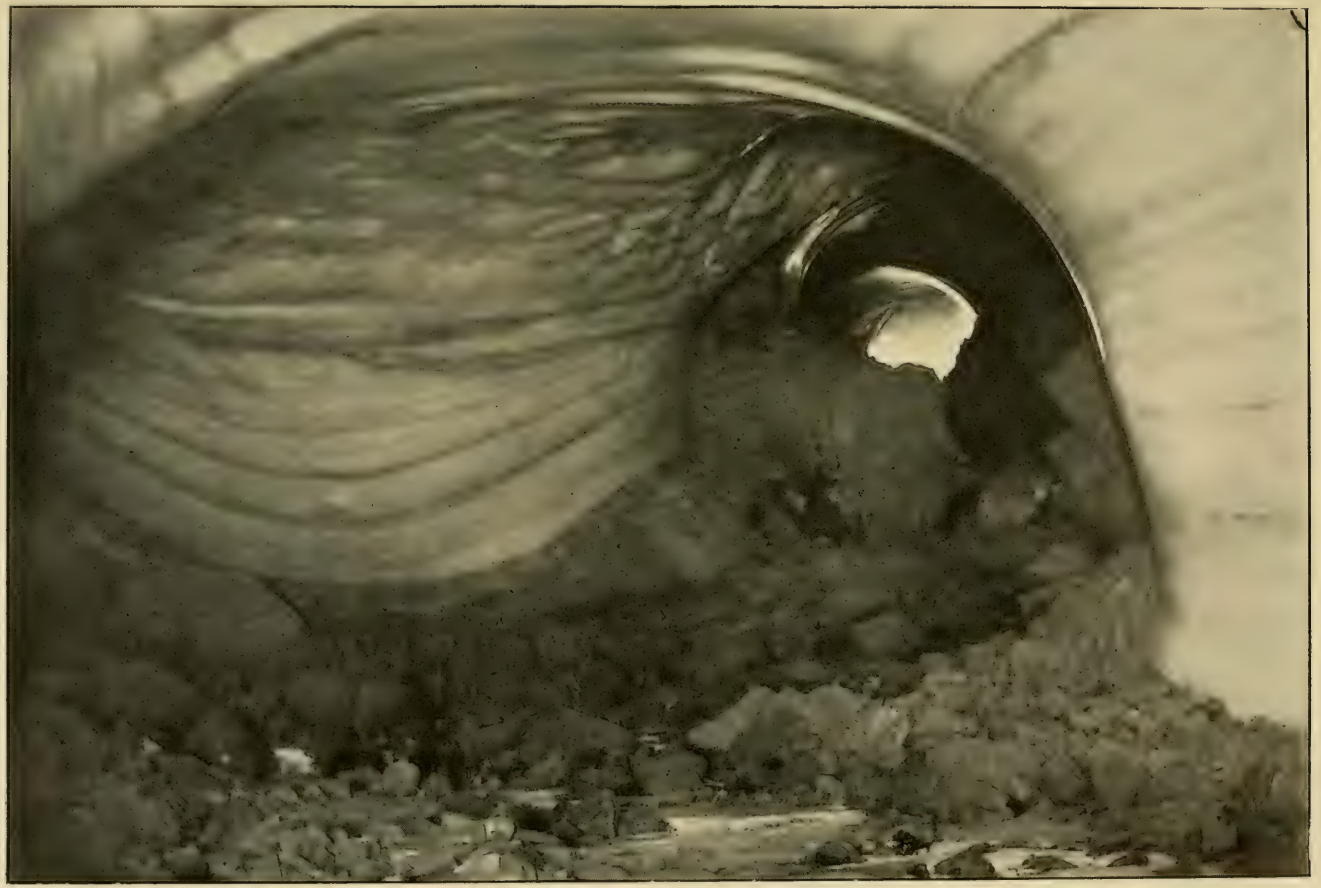


Fig. 95. Vereinigung des nördlichen (*r*) und des westlichen Armes (*l*) der Gnipa-Höhle. Magnesiumaufnahme. September 1907; Lundager phot.

also der Neigung derselben und sammelt sich allmählich auf ihr zu kleinen Bächen. Gegen Ende des Sommers ist der Niederschlag des letzten Jahres an der Oberfläche verwandelt in einen feuchten, grobkörnigen Schnee, der weiter unten in einen vollständigen Schneebrei übergeht. Hier und da reicht der Schneebrei sogar bis zur Oberfläche.

Wenn nun der Frost eintritt, so gefriert der oberste Teil und beschützt damit die tiefer liegenden Teile gegen weitere Schmelzung; hier sickert das Wasser längs der Eisdecke des vorangehenden Herbstes weiter bergab. Der übrige Teil des Schneebreies wird auf diese Weise allmählich von einem sehr erheblichen Teil seines Wassergehalts befreit und bildet, wenn er endlich gefriert, eine stark blasige, weissliche Eismasse. Unmittelbar über der wasserdichten Eisschicht des vorigen Jahres bleibt so, wenn die Kälte schliesslich den Abfluss sperrt, eine Schicht von Wasser und fast aufgelöstem Schneebrei übrig, und hieraus entsteht das klare Blaueis.

An der Oberfläche des Firns selber hat in einer gewissen Zeit Schmelzen und Erstarren mit einander abgewechselt; Staub und Schmutz sind über sie ausgebreitet, und wenn schliesslich die Schmelzung ganz aufhört, ist die Oberfläche umgebildet in eine halbklare, schmutzige Eiskruste — der halbklare, gelblich braune Teil des weissen Eises[1]).

Hiernach ist ersichtlich, dass die Staubhorizonte oft die Tendenz zeigen werden, sich auf die untere Grenze des Blaueises einzustellen. Denn oft schmilzt ja die ganze Neuschneedecke im Sommer vollständig fort, wie es ja auf einem grossen Teil des Gletschers im Sommer 1907 geschah, so dass hier die vorjährige Eisoberfläche zu Tage lag. In diesem Falle müssen sich alle im Neuschnee enthaltenen Staubhorizonte auf diese alte Eisoberfläche niedergeschlagen haben. Auf diese Weise lässt es sich wohl erklären, dass die Staubhorizonte bisweilen trotz ihrer abweichenden Herkunft doch mit der Blaueisschichtung systematisch zusammenzuhängen scheinen.

Ein solches Blaueisband durch die ganze Höhle ohne Unterbrechung zu verfolgen ist, uns nie gelungen. Meist keilten sie aus, oder sie liefen mit anderen zusammen oder endigten gar diskordant auf anderen Schichten. Diese Diskordanzen glaubten wir durch die Annahme erklären zu können, dass die Höhle an der betreffenden

[1]) Die obenstehende Darstellung der Entstehung der Schichtung harmoniert gut mit der von H. Crammer für die Schichtung der Alpenfirne mitgeteilten (H. Crammer, Struktur und Bewegung des Gletschereises, Vortrag i. d. geogr. Ges. in München am 5. Nov. 1908, Erlangen 1909). — Unsere Darstellung, welche in Grönland im Herbst 1907 ohne Kenntnis von Crammers Abhandlung niedergeschrieben ist, kann wohl als Stütze für seine Auffassung der Firnschichtung betrachtet werden.

Stelle einst bei niedrigerem Eisstande offen gewesen war, so dass sich die bei erneuter Schliessung daraufkommenden Schichten diskordant auflagern mussten. Eine solche Diskordanz könnte allerdings auch schon dadurch zu Stande kommen, dass die Abschmelzung in einem Sommer an der betreffenden Stelle des Firns nicht nur den Niederschlag des letzten Winters entfernt hätte, sondern auch einen kleinen oder grösseren Teil des darunter liegenden älteren Eises. Oft sah man das Blaueis auch intermittierend auftreten, gleichsam als Punktreihe anstatt als Linie (vergl. Fig. 83). Die untersten, bodennahen Schichten folgten in sehr markanter Weise den Unebenheiten des Bodens. Die Neigung der Schichten schien durchweg diejenige des Untergrundes etwas zu übertreffen, so dass die Bänder in dem Masse, wie man die Höhle von oben nach unten durchschritt, nach einander im Erdboden verschwanden.

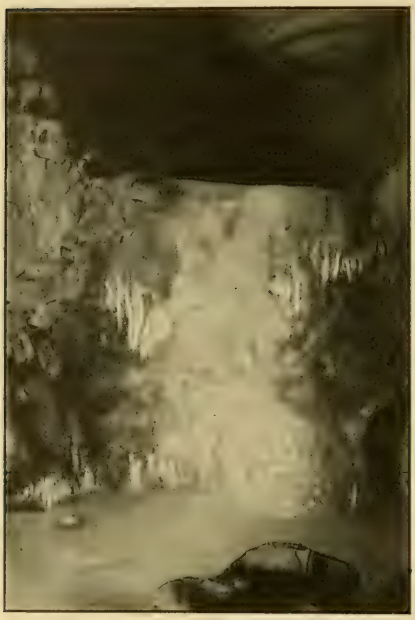


Fig. 96. Gefrorener Wasserfall in der Gnipa-Höhle. Magnesiumaufnahme. September 1907; Koch phot.

Hat man diesen mittelsten Teil der Höhle passiert, so gelangt man noch in vollkommener Dunkelheit an die Teilung (vergl. Fig. 95). Hier laufen über den sich vereinigenden Bächen zwei unterirdische Gewölbe mit vollendeter architektonischer Schönheit zusammen, und es entsteht hier an der Vereinigungsstelle eine Halle von bedeutenden Dimensionen. Verfolgen wir zunächst den nördlichen der beiden Arme, so hat man sofort eine starke Steigung zu überwinden, bei welcher der Bach einen etwa 2 M hohen Fall bildet. Das Getöse des Wassers machte in der geschlossenen Höhle auf die Nerven der Besucher einen sehr starken Eindruck, der durch die vollkommene Dunkelheit dieser Partie noch vermehrt wurde. Unsere Abbildung Fig. 96 zeigt den Fall in gefrorenem Zustande, ebenso wie das vorige Bild mit Hilfe von Magnesiumlicht aufgenommen. Kurz oberhalb dieses kleinen Wasserfalles sind bereits wieder Spuren von Tageslicht zu bemerken, welches vom oberen Ende der Höhle bis hierhin eindringt. Diese nun folgende oberste Partie der Höhle ist von einer ausserordentlichen Pracht, und wirkt auf den Besucher, der von unten

kommt und hier dem Tageslicht entgegensteigt, geradezu märchenhaft. Wie Fig. 86 zeigt, fliesst der Bach hier am Grunde einer kleinen Felskluft, und erst oberhalb derselben schliessen sich die Eismassen in Tonnenwölbungen von packender Regelmässigkeit und Schönheit zusammen. Auch Abbildung 85 ist in diesem Teile aufgenommen, jedoch mit dem Lichte gesehen, so dass hier die prächtigen Lichtwirkungen fehlen. Diese Aufnahme wurde nach dem ersten herbstlichen Schneesturm gemacht; der Boden der Höhle war damals bis zum Wasserfall herab mit Schnee bedeckt, ein Zeichen dafür, mit welcher Gewalt der Wind die Höhle durchweht haben muss, die allerdings gerade in der Haupt-Windrichtung liegt. Schon bei gutem

Fig. 97. Offener Kessel im nördlichen Arm der Gnipa-Höhle. September 1907; Wegener phot.

Wetter und mässigem Winde konnten wir im Innern der Höhle mehrmals Windgeschwindigkeiten bis zu 2 M p. Sek. mit dem Handanemometer beobachten, und es kam nicht selten vor, dass uns unsere Stearinlichter und Lampen ausgeblasen wurden. In dieser Zeit herrschte an den Höhlenwänden eine starke Verdampfung, die besonders dadurch begünstigt wurde, dass das Eis eine viel höhere Temperatur besass als die Luft. So traten einige mit Ölfarbe überzogene Stellen der Eiswand bald um mehrere Millimeter gegen ihre Umgebung hervor. Indessen dürfte diese starke Verdampfung doch auf die Zeit beschränkt sein, wo die Luft noch ungehinderten Zutritt zur Höhle hatte. Schon in der ersten Woche des November wurden sämtliche Eingänge durch einen Schneesturm vollständig verschüttet.

Das Ende dieses nördlichen Armes der Höhle wird durch einen

30—40 M langen, oben offenen Kessel gebildet (vergl. Fig. 97 und Karte), an den sich noch eine ganze Kette kleinerer ähnlicher Kessel anschliesst. In diesem Teile ist der Gletscher offenbar nicht dick genug, um die Höhle zu bergen, die letztere wächst durch den Gletscher hindurch und bildetso jene eigentümlichen Kessel, die den oben befindlichen, von der Höhle nichts ahnenden Wanderer aufs höchste überraschen. Im Winter 1907—08 wurden diese Kessel derartig mit Treibschnee ausgefüllt, dass auch nicht die geringste Spur von ihnen zurückblieb. Im vorangehenden Winter, wo die Schneemenge geringer gewesen war, blieb wenigstens noch an einigen Stellen

Fig. 98. Austritt des Baches aus der Gnipa-Höhle. 4. Juli 1908; Wegener phot.

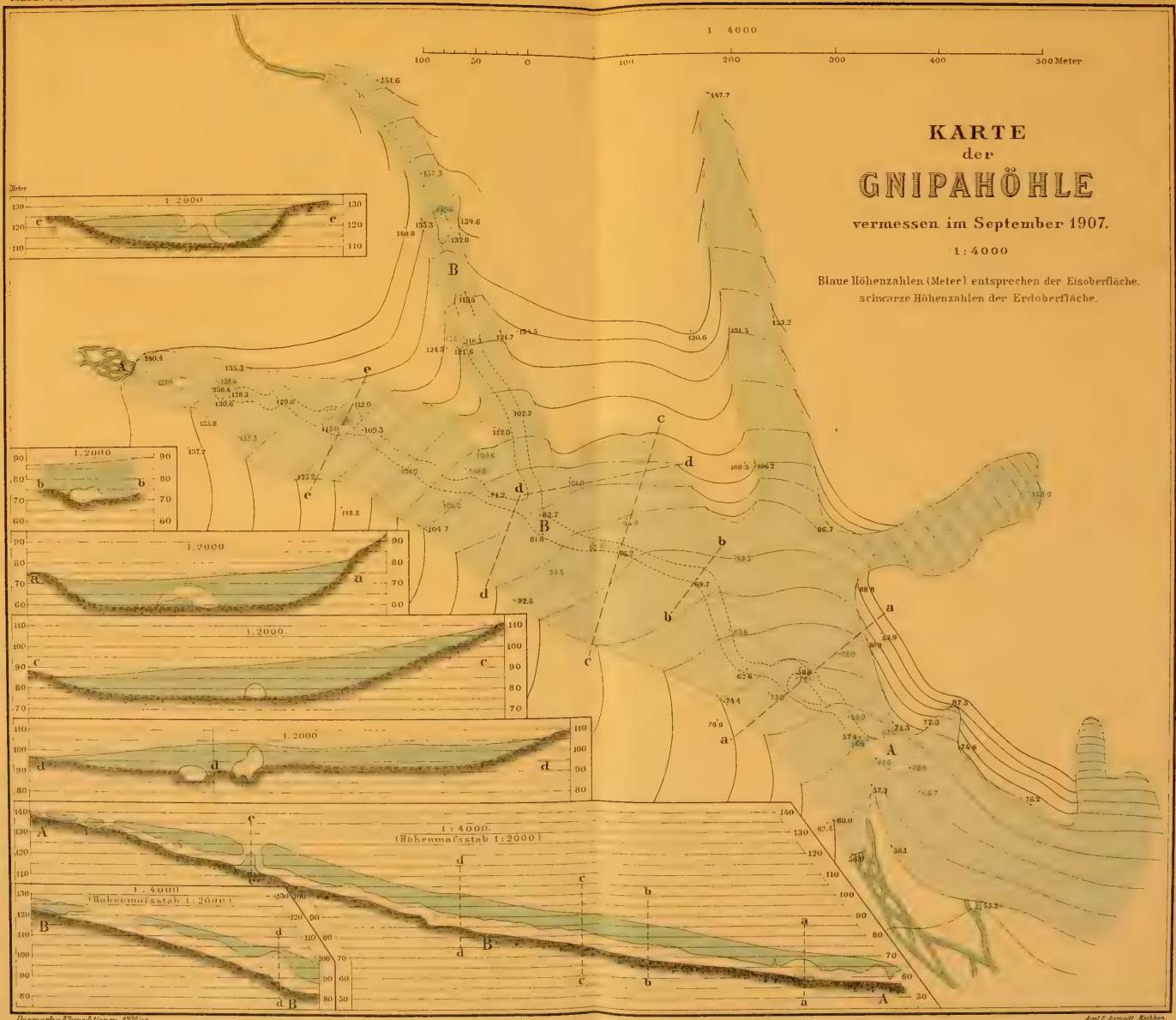
ein Teil der vertikalen Seitenwände der Kessel sichtbar und bildete eine Erscheinung, die wir sahen, uns aber damals nicht deuten konnten. Im Frühjahr 1908 aber waren alle Kessel vollständig eingeebnet. Das Aussehen dieser ganzen Partie des Gletscher ändert sich offenbar bedeutend von Jahr zu Jahr. Die im Winter verschütteten Kessel werden im Sommer nicht wieder frei, vielmehr frisst sich hier der Bach erst mühsam eine neue Höhle von unten her hindurch. Im nördlichen Arm wurde im Herbst 1907 ein solcher Kessel konstatiert, der offenbar im vorangehenden Winter verschüttet worden war. Der Bach hatte in diesem einen Sommer nur vermocht, eine $^1/_2$—1 M hohe Höhle am Boden zu schaffen, die uns gerade noch erlaubte, in liegender Stellung hindurchzukriechen. Es dürfte eine ganze Reihe von Jahren nötig sein, um die Höhle an dieser Stelle soweit hinauf-

wachsen zu lassen, dass sie schliesslich von neuem die Decke durchbricht und auf diese Weise eine neue Auffüllung ermöglicht.

Ganz ähnliche Verhältnisse wie die hier geschilderten herrschen auch im oberen Teil des westlichen Armes der Höhle, welcher im allgemeinen durch grössere Unregelmässigkeit der Gestaltung ausgezeichnet ist. Hier trafen wir einen Kessel (beim Querschnitt *ee* der Karte), welcher offenbar im Winter 1906—07 nur unvollständig ausgefüllt worden war, so dass der Bach hier, statt den neu eingedrungenen Schnee zu unterminieren, um ihn herumfloss und einen Schneekegel in der Mitte des Kessels stehen liess. An dieser Stelle ist die Abbildung 84 aufgenommen.

Im Sommer 1908 konnte beobachtet werden, in welcher Weise der aufbrechende Bach seinen Einzug in die Höhle hielt. Er benutzte dabei zuerst die Oberfläche des Gletschers, wo er sich ein tief eingeschnittenes, stark gewundenes Bett in die Neuschneedecke hineinfrass. Dieser Zustand kann indessen nur kurze Zeit gedauert haben. Am 24. Juni hatte man noch keine Spur des Baches bemerken können. Am 26. aber hatte er bereits den Weg zur Gnipa-Höhle hinab gefunden, und nur die tief eingeschnittene Spur auf der Oberfläche zeigte, dass er zuerst hier oben geflossen war. Auf dem kleinen Gletscher oberhalb des Höhlengletschers floss er auch jetzt noch über die Oberfläche fort.

Die Wassermengen des Baches nahmen in den letzten Tagen des Juni gewaltig zu und waren, wie die Abbildung 98 zeigt, noch Anfang Juli, kurz vor der Abreise der Expedition, so mächtig, dass ein Betreten der Höhle nicht möglich war.



Danmark–Ekspeditionen 1906/08.
Lyst E. Arnoldt, Kjøbenh.

DANMARKS HAVN AND ENVIRONS.

NORDÖST-GRÖNLAND
FRA 76° 8' TIL 75° NORDLIG BREDE.
Maalestok 1:500000
Kilometer
Ieistærkning.
JOKELBUGTEN
Ile de France
SKÆRFJORDEN
GERMANIA LAND
DOVE BUGT
STORSTRØMMEN
DRONNING LOUISES LAND
L. BISTRUPS BRÆ
Store kuldenæv
Korfod-Hansens Bræ

NORDÖST-GRÖNLAND

Maalestok 1 : 1000000

NORDÖST-GRÖNLAND

SYDLIGE BLAD

II.

SURVEY OF NORTHEAST GREENLAND

BY

I. P. KOCH

1916

INTRODUCTION

Now that the geographical survey of Greenland is drawing to a close, by means of which survey we have arrived at a primary knowledge of the distribution of land and water, of the formation of the surface, of the extension of the inland ice, this knowledge is becoming the basis of new problems and new questions, the correct answers to which will, to a certain extent, depend upon more accurate surveys being taken. This holds good of a series of problems which directly or indirectly relate to the extent of the inland ice or variations of same.

It will, however, always be a difficult thing to find people with the necessary professional training willing to undertake the more accurate surveys. The young men who have the time and opportunity to travel in Greenland have, as a rule, only received a general theoretical education as regards mathematical and nautical subjects, and they thus lack not only the theoretical, but in particular also the special practical knowledge of survey work which will be requisite in this instance.

This theoretical knowledge, as adjusted to the objects of which in the first place I am thinking, need not be very deep. On the other hand it is not very easy to acquire, because the existing textbooks aim at giving a different and much more exhaustive training whereas they do not at all, as regards certain questions, mention the methods which are most suitable for arctic conditions. A thorough theoretical knowledge acquired through forced studies, which have not had the chance to become rooted by means of practical training will, however, be of no great use. At best the cartographer when arriving in Greenland and being left entirely to his own resources, will rather quickly realize "that theory and practice are widely different things", and that in order to do part of the work which he set out to do, he must emancipate himself from his cherished theories and, instead of that, have recourse to his commonsense. But a sudden transition of this kind is not easily made, at any rate not without

suffering by it, and it requires a sure, instinctive feeling of what is the central point, which feeling can only, as a rule, be acquired by practical training.

These considerations have, to a certain extent, guided me in the preparation of certain parts of my account of the surveying of North-east Greenland. As regards the work in the Observatory, the base measuring, the triangulation with the attendant levelling, I have taken pains not only to set forth the facts in such a manner that they may be critically appraised, but also to emphasize the purely practical conditions, to such an extent that a direct imitation ought to be possible for any man who, though possessed of some theoretical training, yet lacks the requisite practical knowledge. An exception is made in the case of the extremely unimportant spirit levelling of the base. I have here omitted mentioning practical conditions, because my instrument was of a very antiquated make. Among other things the reticule of the instrument was not adapted for measuring the distance, and this process had to be carried out by means of the micrometer screw.

Also in writing about the purely geographical surveying, I have thought it right to mention certain conditions which, according to my experience, are interesting from a practical point of view.

The Cartographic Object of the Expedition.

In 1870 the Germaniaexpedition[1]) had sent out a hand sledge party in a northern direction from the Pendulum Islands. It reached as far as 77° 2′, but in consequence of the forced and partly unfavourable travelling conditions the charting from Haystack (75° 45′) became more superficial than was desirable; in particular the coast round Teufelkap and in Dove Bay as well as the outer coast at Kap Bismarck was left practically unexplored.

In 1905 the Belgica[2]) traversed the open land water along the outer islands from about 76° to 78°. During this trip a successful attempt was made to determine roughly the position of the outer coast as far as 78°, as well as to indicate the existence and approximate position of the land as far as about 79°.

From 79° to 82° no data respecting the country were available.

In 1892 and 1895 Peary[3]) had crossed the inland ice from Cape York, and at 81° 40′ and 35° west of Greenwich he had found a

[1]) Die zweite deutsche Nordpolfahrt in den Jahren 1869 und 1870 unter Führung des Capt. Koldewey. Leipzig 1873—74.

[2]) duc d'Orléans: Croisière océanographique dans la Mer de Grönland en 1905. Bruxelles 1907.

[3]) Northward over the Great Ice by R. E. Peary. London 1898.

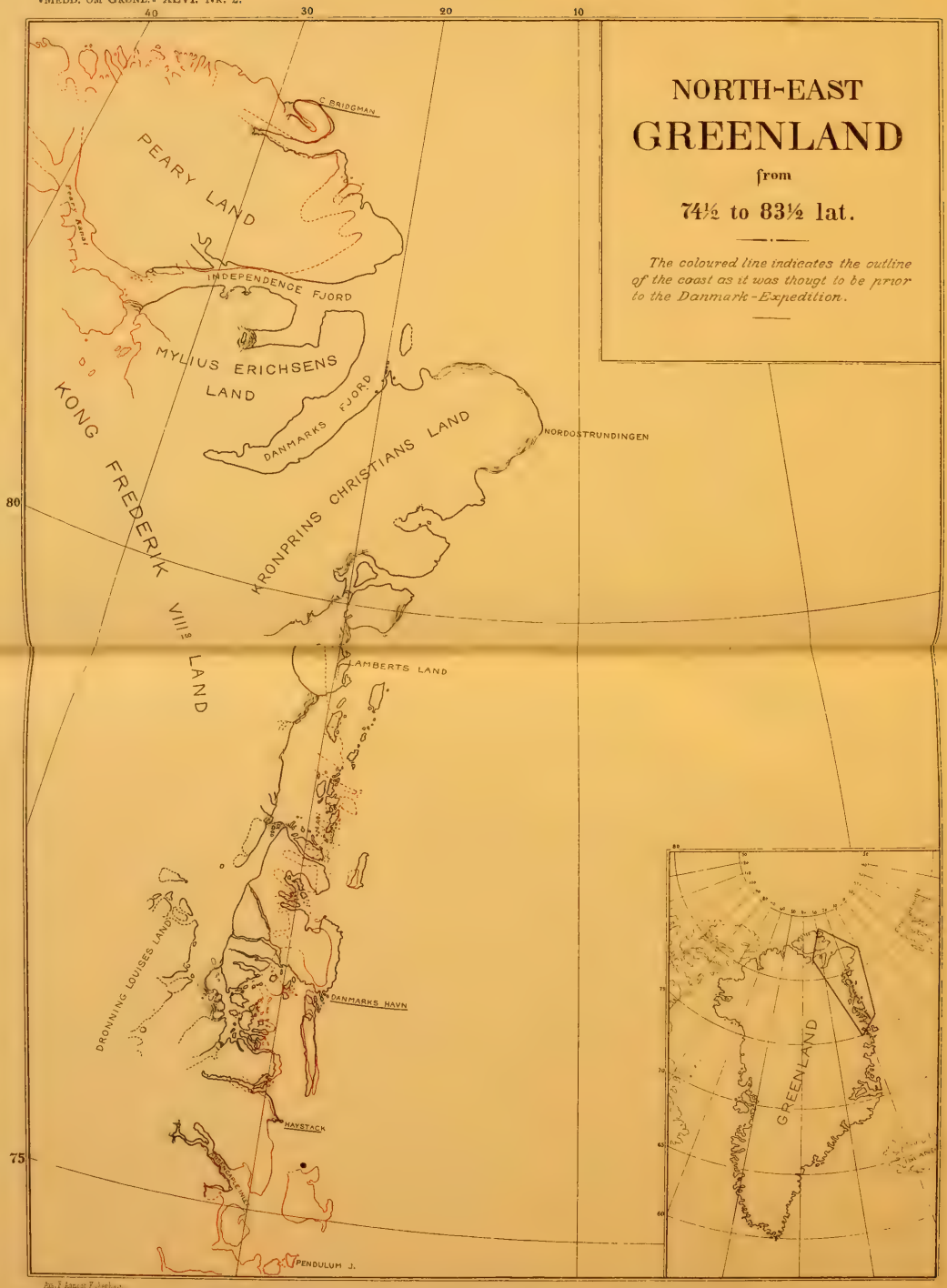


Fig. 1. Map sketch representing the chartographic object of the Danmark-Ekspedition.

country which he could not but think was a part of the east coast of Greenland. In the course of both of these voyages PEARY had established the fact that a great fjord or sound stretched from the east in a westerly direction south of Peary Land, and he supposed that this latter country was an island.

In 1900 PEARY[1]) travelled north from the district round Cape York through Robeson Channel; he passed the northernmost point of Greenland and penetrated from the north along the east coast of Peary Land as far as about 83°. The last stretch from 83½° to 83° was covered under unfavourable circumstances as regards weather conditions, and the map was consequently less complete.

The accompanying map sketch (Fig. 1) presents the chief cartographic object of the expedition. Apart from the Ardencaple Inlet and the problem of the Peary Channel the geographical surveys of the Danmark-Ekspedition were thus, according to the programme, made to include the east coast of Greenland from Haystack to Kap Bridgman. This stretch might a priori be estimated at about 1000 kilometres, but in reality it turned out to be considerably longer.

The programme of the expedition as regards survey work was a very extensive one, in all a little more than a sixth of the whole outline of Greenland, and add to this that we had to reckon with considerable obstacles on the part of nature herself. Our success in carrying out our programme was first and foremost due to the indomitable energy of MYLIUS-ERICHSEN, and his firm belief that he would be successful. We were all carried away by his dominating personality and his confidence, and this was felt much more in the cartographical work than in any other field of activity.

The courage and indefatigable labours of my comrades provided the material from which the maps were made. The particular activity of each of us in the service of cartography will be touched upon later on; in this place I shall only beg to call to mind the two men, who lost their lives when working in the cause of science: Lieut. HAGEN, who finished his map sketches of Danmarks Fjord and Independence Fjord[2]) at a period when hunger and want would have broken the energy of a weaker man and one endowed with less will power, and BRØNLUND, who with frozen feet dragged himself to the depot on Lambert's Land and there, with certain death staring him in the face, arranged everything so that the valuable map sketches should not be lost.

[1]) Bulletin, Vol. IV, No. 1, Geographical Society of Philadelphia.

[2]) At the time of the publication of the map of the expedition it was not known that there was no "Peary Channel". In the maps we consequently find Independence Sund and not Independence Fjord.

Besides the chief cartographic object of the expedition there were several others of a secondary character:

1) The making of minute survey maps of the winter quarters and their immediate surroundings, as well as of other localities, wherever the scientists might wish for such maps.

2) An accurate determination of the geographical co-ordinates of the winter quarters.

3) An investigation of the conditions of refraction.

Instruments.

During the early part of the winter of 1905—06 Mylius-Erichsen commissioned me to take charge of the measuring of the stretch from Ardencaple Inlet to Kap Bridgman. This work had to be done during the stay of the Danmark-Ekspedition in Northeast Greenland, but it was limited in so far as the expedition, according to the programme, was to go south to Franz Joseph's Fjord already after the first winter. On the other hand I could take it for granted that the chief object of the expedition being a cartographical one, particular energy would be directed to this work, even if other departments had to suffer.

It was not only Hagen who was particularly told off to assist with the cartographical work, but nearly all of those who were going to accompany me on the expedition, who took a very great interest in the survey of the country, which circumstance contributed very much to strengthen my own energy and belief that we should succeed. To be sure, I was the only one among the members of the expedition who until then had been occupied with practical survey work, but I did not regard this as vitally important. From experience I knew how easy it is for those who have received a practical education to carry out a geographical survey of comparatively small and limited fields, when using primitive instruments and the corresponding primitive methods.

The fundamental idea of our programme, as laid down at home, was that the cartographical work should be done by means of sledge journeys, though surveys were also to be made from the ship on as large a scale as possible. However, as I did not expect much from this latter method, the ship of the expedition was not provided with special instruments for this purpose, and owing to the unfavourable ice conditions no attempt was made to undertake surveys from the ship.

The conditions on long sledge trips through uninhabited tracts are of such a nature that it is hardly possible to undertake photographic surveys. Not only is the photo-theodolite too complicated

and too sensitive to cold and damp, but the fact that the negatives can only be developed after each trip is ended, everywhere necessitates the making of perspective sketches of the land, even if it is also photographed. While photogrammetry must thus be considered impracticable for the carrying out of the chief cartographical programme, there would have been good reason to attemp stereo-photogrammetry applied to minute surveys in the neighbourhood of the winter quarters. But owing to our total lack of knowledge of the conditions of the land which we set out to discover, I could not, with any certainty, take it for granted that the stereo-photo-theodolite could be used. Consequently, I also had to base the minute survey on methods which had stood the test under arctic conditions, and therefore I dared not propose the purchase of the rather expensive stereo-photo-theodolite.

It is a universal misconception that the sextant is an indispensable instrument on voyages of geographical exploration, and therefore one usually brings a sextant and an artificial horizon in addition to a theodolite. In former times, when the determination of longitude by lunar distances played a great part, and when the theodolite had not reached its present stage of perfection as regards lightness, safe packing and transportability, it was justifiable to bring a sextant. Now, however, things are quite different. A small universal instrument is just as capable of resisting rough handling as a sextant; it gives the same accuracy in the astronomical determinations as a large sextant does; it is, in a much higher degree than the sextant, independent of wind and of the altitude of the sun, and finally it may be said to be greatly superior to the sextant in every form of terrestrial survey. For nautical use there were, however, in the ship of the expedition a large number of sextants, which gave me a chance of taking an artificial horizon with me, so that in cases of emergency the sextants could be used ashore.

Inventory of the instruments etc. intended for use in the survey work.

Object	cost (danish crowns)	supplied by	to be used
1 field observatory	300	Københavns Pavillonbyggeri	in the winter quarters
1 granite pillar	10	Wienbergs Stenhuggeri, Copenhagen	in the Observatory
4 barrels cement			- - —
1 iron table		Wagners Metalvarefabrik, Copenhagen	- - —

Object	cost (danish crown)	supplied by	to be used
1 universal instrument	800	Geographical Institute of Berlin	in the Observatory
1 moon telescope	110	Reinfelder&Hertel, München	- - —
dry cells		Hellesens Enke & Ludvigsen, Copenhagen	- - —
electrical bulb holders		Otto Bruun, Copenhagen	- - —
2 kitchen lamps			
6 pocket chronometers	2350	Bonniksen, Coventry	- - — and on sledge trips
2 watches	130	Ranch, Copenhagen	on sledge trips
1 5 metre steel tape	10	Thiele, --	for measurement of base lines & on sledge trips
2 measuring tapes	4	— —	
6 travelling universal instruments	2700	Max Hildebrand, Freiberg	on sledge trips
14 pocket aneroid barometers	350	Thiele, Copenhagen	- — —
7 pocket compasses	30	— —	- — —
100 swinging thermometers	275	Jacob, —	- — —
12 alchohol thermometers	72	— —	- — —
6 drawing portfolios		Levison, —	- — —
2 Souchier distance meters	55	Thiele, —	- — —
6 Zeiss prism field glasses	660	— —	- the triangulation & on sledge trips
dry cells		Hellesens Enke & Ludvigsen, Copenhagen	on sledge trips
electrical bulb holders		Otto Bruun, Copenhagen	- — —
1 level quadrant[1])	55	Butenschön, Bahrenfeld, Hamburg	- — --
1 artificial horizon	20	Cornelius Knudsen, Copenhagen	- — —
1 24 metre steel tape with iron plugs	40	Thiele, Copenhagen	for measurement of base lines
1 Stampher levelling instrument		lent by the Hydrographic Office, Copenhagen	for measurement of base lines
30 bamboo canes	20	Börgesen, Copenhagen	for the triangulation
30 brass bolts		Baadh & Winter, Copenhagen	- - —
4 stone bores, 1 hammer		Peter Ibsen, Copenhagen	- - —
60 square metres white linen		Messen, Copenhagen	- - —
2 universal diopter rules		lent by the General Staff	for minute survey
2 plane tables with accessories		— - — — —	- — —
4 levelling rods		— - — — —	- — —
1 stereo-telemeter	550	Thiele, Copenhagen	- — —
3 hodometers	425	Holmerud, Christiania	on sledge trips

[1]) This instrument is constructed for use on balloon trips. The horizontal direction is determined by a level reflecting in the telescope tube. On the Danmark-Ekspedition it was intended for use when navigating on the inland ice. However, it was never used.

In the chartographical equipment must further be included:

7—6—5- and 4-placed tables of logarithms.
ALBRECHT: Formlen und Hilfstafeln für geogr. Ortsbestimmungen.
MOHN: Barometrisk Højdemaaling.
Nautical Almanac 1906—7—8, full edition.
— — — small edition.
Star map.
Star globe.
3 engineer's scales (rules)
Drawing paper and requisites.

A more detailed account af the instruments etc. will be given in the following chapters.

CHAPTER I.

The Work in the Observatory.

The Observatory. Experience gained as regards more accurate astronomical observations in high arctic regions.

The Observatory was made of wood, the single parts being put together before we left home. The flooring was 2.7 m square. The walls the height of which was 1.5 m were double, having besides the outer covering only a thin inner one of planed and tongued planks. In the southern wall there was a door.

The roof formed a truncated four-sided pyramid. It consisted of nine single parts all covered with tarred felt, viz. four corner pieces, five trapdoors (facing north, south, east and west respectively and one in the roof). The trapdoor in the roof, 0.7 by 0,7 m, was fastened with a couple of long iron hooks, by means of which it could be lifted and re-fastened from the inside. The four trapdoors facing north, south, east and west were 0.7 m in breath; they could be taken off and fastened separately, as soon as the trapdoor in the roof was removed, or only slightly lifted. Each of them was fastened to the upper edge of the wall by means of a small iron hook. The corner pieces were fixed by their own weight, without hooks. The whole roof could be removed and put up again by two men in the course of five minutes without using a pair of steps.

The walls were painted white on the outside, while the roof in consequence of its being covered with tarred felt was black. The object of this was partly that the Observatory itself might be used as a "cairn" during the triangulation, partly to insure that the difference of temperature inside and outside the Observatory should be as small as possible, when the roof was removed.

The inner fittings consisted — apart from the granite pillar with instrument — of one fixed table, one wooden box, which served as a chair, the electrical installation, one celestial map (on the wall) and two pairs of rush shoes.

The Observatory was a good one and the dimensions suitable. The fact that floor, walls etc. were put together at home made the

erection of the house in Greenland an easy matter. As the single parts were so small that they could be comfortably stowed in the expedition ship, they vere not damaged during the voyage or during the unloading in Greenland.[1])

The hatch door in the roof turned out to be impracticable. It was too difficult to take it off and put it on, when the instrument was placed on the pillar; it happened several times during a snowstorm that the iron hooks straightened out, and the hatch door was carried away up to a hundred metres; once it fell down and damaged the instrument. On the other hand this hatch door turned out to be quite superfluous, because the Observatory during a storm was always more or less filled with snow, whether the hatch door was fastened or not, but this inconvenience meant nothing more than an hour's shovelling after each storm.

Fig. 2. The Observatory after a snowstorm. The trapdoor in the roof, the trapdoors facing south and east as well as the southeasterly corner piece have been removed.

During the early part of September 1906 the granite pillar for the Observatory was taken ashore. The pillar was prismatic, placed on a base, 0.35 m square; the length of the pillar was 1.3 m, its weight about 450 kg. It was cast into a square cement plinth, which by means of a slight excavation was made to rest on the solid rock. The side of this plinth was 1.3 m, and it was about 0.3 m thick. For the plinth we used about a barrel and a half of cement, and the sand for same was made by screening rubble on the spot itself.

On the surface of the pillar there were four holes, the three of

[1]) As regards the dwelling house, the "Villa", the opposite was the case. The large panels of which the latter consisted warped and were so damaged during the voyage that when we arrived in Greenland they had to be split up into separate boards and planks and then put together once more, before the house could be erected.

which formed the vertices of an equiangular triangle, while the fourth hole was in the centre of this triangle. In the latter hole a small brass bolt was placed; in the three others were cast the legs of a solid iron table (Fig. 3) the top of which was about 2.5 cm thick. In the centre of the top of the table there was a hole for the central screw of the instrument. When the instrument was clamped on to the iron table, it was thus solidly connected with the granite pillar. When adjusting it by means of letting the plumb down over the brass bolt in the surface of the pillar (see Fig. 3), one could with great accuracy replace the instrument in its original position, whenever it had been removed from the pillar, which circumstance, however, came to be of no importance in our case, as we did not succeed in getting a meridian mark of which we could make any practical use.[1])

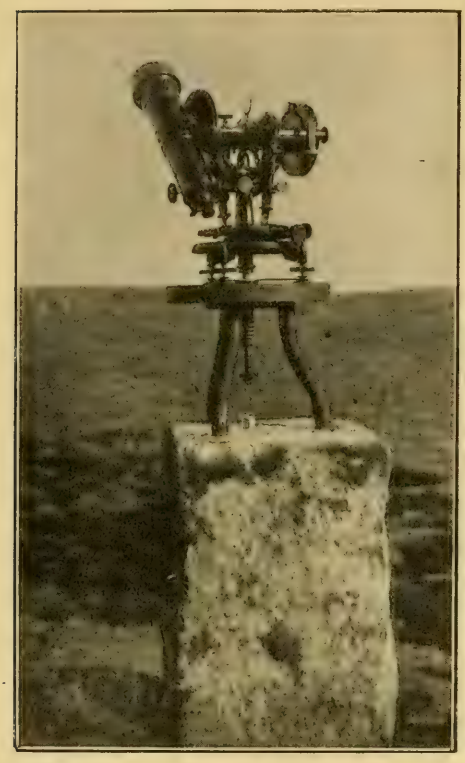


Fig. 3. Granite pillar with iron table and instrument.

By levelling with a Stampher levelling instrument the height over mean sea level was determined as:

Brass bolt in the granite pillar	13.46 m
Top of the iron table .	13.67 -
Telescope	13.89 -
Upper part of the wall of the Observatory. .	13.84 -

From this it will appear that from the Observatory we could measure zenith distances of a little more than 90°.

The construction of the granite pillar turned out to be practical, and this was also the case with the manner in which the fundamental plinth was arranged.

We had originally intended to establish a meridian mark, chiefly to be used in the observations of time. However, we had made no

[1]) An error in the adjustment through the plumb of 5 mm must, in case the distance of the meridian mark was one kilometre, occasion an error in azimuth of $\frac{5}{10^6}$ = about 1″.

special preparations on account of this, as I had thought that it would be easy enough to improvise a meridian mark by placing a wooden screen with a couple of little holes at a distance of a few kilometres, a lantern placed behind the screen serving at night to make the holes visible. The natural conditions of the country, however, did not permit of the erection of a meridian mark towards south, where the nearest land — Lille Koldewey — lay at a distance of nearly 13 kilometres. In the north we might, it is true, have put up a meridian mark at a proper distance, but this would scarcely have been of any practical value, because it would not have been possible during the winter, in the dark, to reach the lantern, whenever it was to be lighted or extinguished, without submitting to hardships disproportionate to the result.

Under arctic conditions one must be prepared to be able to do without a meridian mark, and consequently a universal instrument will generally be preferable to a transit instrument. However, if one wants to use the meridian mark, the latter ought to be connected with the observatory by an electric current, so that it would be possible to light and extinguish the light of the meridian mark from there.

The universal instrument, which was manufactured by Max Hildebrand, Freiberg, was the one used by Professor E. v. Drygalski on the Gauss Expedition.

The circles, the diameters of which were 13.5 cm were divided into $^1/_6°$. The reading of the vertical circle was done by means of reading microscopes of the usual kind. The smallest division on the graduated head being 5″, estimations could be made in half seconds. The horizontal circle had a scale microscope which allowed of reading in tenths of minutes.

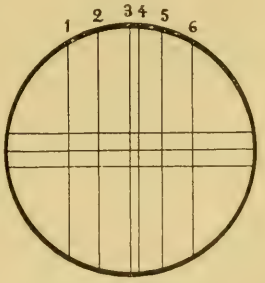


Fig. 4.

The finder was divided into whole degrees, the reading being made by means of an index.

The angular value of the division of the level was in the case of the level of the axis 4″.4, for the level of the vertical circle 5″.4. Both levels were provided with air-chambers, and they were both encased in a protective glass tube.

The telescope was eccentric. The objective aperture was 6.2 cm. The two eye pieces (oculars) had a magnifying power of twenty and thirty times respectively.

The reticule was, as indicated by Fig. 4 arranged with three horizontal and six transit threads. Thread No. 3 was the one which

gave the smallest collimation constant; it was consequently used as a middle thread. The thread intervals appear from the below reduction to thread No. 3 for $\delta = 0$.

Thread No.	1	2	4	5	6
Reduction	$30^s.5$	$15^s.3$	$3^s.8$	$15^s.6$	$30^s.7$

The interval between the horizontal threads was about 2′. The threads were rendered visible at night by light thrown into the interior of the telescope through a pane off the horizontal axis of rotation.

The special fitting up of the telescope with the large object glass and the inserted negative lens to shorten the focal length was hardly a success. It is true that the great intensity of the large field was very convenient, but the images of the stars were not well defined — the bright ones of the first or second magnitude had a wing on the one side — and consequently we did not attain the accuracy which would have been attained by an ordinary telescope, suited to the instrument.

In the course of all observations made while the sun was visible, it proved difficult to protect the instrument against the insolation, which in arctic regions may become sufficiently powerful to produce a difference in the temperature of the air and the black bulb temperature of as much as 40° (Centigrade). In consequence the levels of a well verified instrument might oscillate in rather a disagreeable manner, as soon as the rays of the sun fell on the single parts of the instrument or on the iron table. The top and legs of the iron table were painted white, but this arrangement turned out to be insufficient, and it consequently became necessary to wrap up the table in a petticoat of white linen, and in this manner the difficulties as regards the iron table were surmounted.

The instrument itself was more difficult to screen from the sun, because the screen covering it might easily disturb the manipulation; the insolation was here more dangerous, as there was no alteration in the inclination of the axis corresponding to the extension and contraction of the setting and legs of the level, and the consequent oscillation of the latter. Add to this that the level under the rays of the sun became so slow as to make the adjustment of the bubble uncertain. The difficulty was to a certain extent remedied by means of a little shade of white linen in a frame of bamboo cane. It was placed in a lamp holder, which was fastened to the edge of the iron table, in such a manner that the level with its setting and legs were in the shade. The lamp holder had a movable joint, which allowed

of the necessary shifting when the position of the telescope was altered.

The best manner of guarding against the effects of the rays of the sun was by letting the instrument stand uncovered in the direct rays about an hour before the observation, and in such a manner that both ends of the frame of the level were illumined. Then immediately before the observation the shade was attached and the instrument verified. If we had not taken care that both ends of the level frame were illumined, the contraction, when the shade was attached, varied at the ends, and the instrument then got out of order shortly after the verification.

The instrument, when not in use, was covered with an oil-cloth bag, which was dropped over it. The telescope was then always adjusted in such a manner that the object glass pointed towards the zenith. During a snowstorm in October 1906 the Observatory was partly filled with snow, which penetrated everywhere through the fine crannies of the joints. On the top of the instrument was a snow column of about 1/2 metre high, and the weight of this, which chiefly weighed on the telescope itself, lifted the opposite end of the horizontal axis of rotation out of position. In order to prevent a repetition, an oil-cloth bag, about 1.5 metres long with the bottom upwards, was hung from the roof of the Observatory so as to enclose the instrument.

The greatest difficulties were due to the low temperature[1]). To make astronomical observations in a temperature of $\div 20°$ to $\div 30°$ (Centigrade) is of course not a pleasant experience, but the low temperature only plays a minor part as regards the well-being of the observer, partly on account of the comparatively small amount of moisture in the air, and partly because one soon learns to protect oneself from the cold by means of suitable clothing, and by covering those parts of the instrument which one cannot avoid touching — screws, ocular frames etc. — with chamois leather, ebonite and such like.

The low temperature, however, affects the instrument in a most troublesome manner, and only with the utmost care can we protect ourselves against the effects.

In consequence of the moisture of the exhaled air and of the skin the instrument becomes covered with rime. This cannot be avoided altogether, and one must always have a bit of chamois

[1]) The lowest temperature recorded during an observation from the permanent Observatory is 29° (Centigrade). On sledge trips as low a temperature as 35° has been recorded.

leather in readiness to wipe the oculars and other parts of the instruments; likewise one may very considerably diminish the rime of the air exhaled by tying a silk kerchief triangularly folded over the nose and binding it firmly at the back of the head. The moisture is then condensed on the inner side of the kerchief, which becomes completely covered with ice. It is rather disagreeable to have this ice sheet dangling before one's face, but one has to put up with it.

The danger of the instruments becoming covered with rime is by the way not dependent upon the temperature only. As a general rule it may be stated that when the moisture in the air exhaled condenses in the atmosphere, one must be particularly careful; if one cannot see the mist rising from the air exhaled, a kerchief is hardly necessary.

The worst of all is when the rime settles on the horizontal axis of rotation under the legs of the striding level, because the level then indicates an erroneous inclination of the axis. This also takes place, as soon as the oil freezes, which happens at about $\div 20°$ (Centigrade). But already at an earlier period it becomes thick and at the vertical movement of the telescope gathers in streaks along the generators of the horizontal pivot. These streaks also make the surface of the pivots uneven, and this, in its turn, renders the readings of the striding level illusory. In order to guard oneself against this the oil must, before any observations are made, be carefully wiped or washed off the pivots and the V's; in the same manner the feet of the striding level must be wiped. In spite of every precaution ice crystals will, however, now and then settle on the pivots, and as the latter nearly always from there pass on to the striding level and remain there, it may be necessary to wipe the feet of the level every time it is reversed.

The level is also in other ways influenced by the cold. Only by holding one's hand over the one end of the level does one influence the position of the bubble, in that the heat emanating from the hand occasions the expansion of the metal frame. Hand and wrist must consequently be covered with mittens and wristlets.

As a matter of course it is not convenient to use an ordinary hand lantern for the purpose of reading the level. A small electric hand lamp is better, because the radiation of heat is here so much smaller, but the level also reacts upon such a lamp, if lighted for too long a period or at too short a distance.

The lack of a meridian mark generally caused me to use transits on the vertical of Polaris for the determination of time. But by this very method the accuracy of the determination of time is in the main dependent on the accuracy with which the inclination of the axis

can be determined (the correction for the inclination of the axis is $i \sec \varphi$, where $\sec \varphi$ for Danmarks Havn is $= 4.37$).

The use of very delicate levels for determining the inclinations will in consequence of what is stated above not answer the purpose. It would be better to use levels which have a somewhat stronger curvature than the one which is generally used for the instrument. These levels are quicker and more certain of adjustment, and so one will gain time to wipe the pivots and feet of the level, every time it is reversed.

It will, I suppose, be a good plan to bring two or three levels of varying delicacy, each in a separate frame and ready for use. One might then, according to the circumstances, use the one which answered the purpose best. If we count upon using the observatory instrument on sledge trips, in other words set up on a tripod, it would undoubtedly also be a practical measure to carry a less delicate vertical level than the one corresponding to the permanent fittings of the granite pillar in the observatory.

The watches. The fact that the box-chronometer of the ship had necessarily to remain on board under the special supervision of the officers prevented our using this watch for the purpose of Observatory observations. Consequently for this purpose I had to rely entirely on pocket watches, and experience showed that they could yield a rate, the accuracy of which was reasonably proportionate to that of the observations.

The expedition was provided with six Karrusel watches from B. Bonniksen, Coventry. These were first and foremost intended for use during sledge trips; however, it was also the idea to use them in an attempt to find the difference of longitude between Copenhagen and Greenland by portable chronometers, as well as later on in the permanent Observatory, for which reason two of them were regulated according to sidereal time.

Allready during the autumn of the first year the glass of the mean time chronometer 57310 was broken, when we met with an accident on one of our sledge trips, and unfortunately it turned out that none of the spare glasses fitted it. It therefore became necessary to enclose the watch in a particular tin case, in which a glass was placed, but as this did not fit very tightly, the watch could not be used on sledge trips. So we placed it in a double watch box in the "Villa", and it was afterwards used as the standard watch of the expedition.

The measure adopted in a milder climate, that is to leave the chronometer unprotected in the observatory itself, where the changes

in the temperature are comparatively slow and slight, will not do in arctic regions. Already during the autumn of the first year our experience, on various sledge trips, was that the watches stopped, when their temperature fell below ÷ 25° (Centigrade). Consequently the watches at home had to be kept in the "Villa", where they stood on the table in their cases, next to the standard watch. Here the temperature was during the day + 10° to + 15° (Centigrade), at night during the coldest season, as a rule a couple of degrees below zero; on one occasion the temperature round the watches was as low as ÷ 9° (Centigrade). The Karrusel watches stood these changes fairly well, and they maintained a rate which was sufficiently even and correct in proportion to the accuracy which was desirable as regards knowing the exact time. (The accuracy of observation could, in the case of the determinations of time, under favourable conditions be carried as far as tenths of a second).

In the course of the observations of the sun, an ordinarily good pocket watch was used, whereas at night a Karrusel watch 57203 was used, which was regulated according to sidereal time, and thus every time had to be taken to the Observatory. However, comparisons before and after the observations showed, already at a temperature of ÷ 10° (Centigrade), that the rate of the watch was subject to change, when exposed to the low temperature for a certain period, say for instance more than an hour. In order to remedy this defect 57203 was placed in a glass bowl with a cut glass rim fitted with a cover which became airtight, when the rim was smeared with vaseline. The glass bowl was lined with felt. This arrangement was a great improvement, though it could not altogether protect the observation watch against the influence of cold.

On October 28th 1907 at a temperature of ÷ 18° (Centigrade) a determination for longitude by the moon was made; this observation fell into two periods, each lasting about an hour, with an interval of a few minutes. The comparisons taken before and after the observation, as well as in the interval between the two periods, showed that the observation watch in the first period had kept its rate unaltered, whereas it had in the last period gained about half a second. This might be supplemented by a number of similar examples.

As the air in the glass bowl often contained greater quantities of moisture than what corresponded to the saturated vapour of the surrounding temperature, it often happened that the inside of the glass cover became covered with rime, so that the reading of the watch was rendered rather difficult. This we could guard ourselves against by carrying the glass bowl containing the watch into the open air, some time before the observation, taking off the cover,

greasing the cut glass rim and replacing the cover, before the bowl was taken back to the heated room. By putting a hygroscopic substance e. g. chloride of calcium into the glass bowl one might presumably also have prevented the formation of rime, but it was not possible to make experiments in this direction on the expedition.

The watches were made to run for 30 to 36 hours at a stretch. Both on sledge trips and at home they were from prudential motives wound twice during the twenty-four hours.

The Karrusel watches were good; in particular it was surprising how well they withstood the rather rough treatment on sledge trips.

As observation barometer we used the standard barometer of the expedition, a mercurial barometer which was hung in the "Villa", and the cup of which was 7.6 m lower than the telescope.

The reading of the barometer was to be corrected by means of

The index error of the barometer	÷ 0.5 mm
Correction for the height of the telescope above the barometer	÷ 0.7 —
Reduction to 45° latitude.	+ 1.8 —
Sum total of constant corrections . .	+ 0.6 mm

To measure the temperature a swinging thermometer was used, the correction of which was zero. As the use of the swinging thermometer requires space, one must go outside the Observatory whenever it has to be swung, and consequently one could not measure the temperature at the objective of the telescope, as one strictly speaking ought to do. Such a proceeding is by no means permissible in the case of observations requiring due consideration of the refraction, inasmuch as there may be such a great difference between the temperature inside the observatory and outside it, that it comes to play even a rather great part in proportion to the accuracy of the observation. Even if the 0.7 m wide meridian aperture of the Observatory were open throughout its length from south to north, the difference of temperature between the air inside and outside the Observatory at noon, when the sun was visible might, however, rise to a couple of degrees; at night and when electric light was used the difference was on the contrary imperceptible. Nocturnal experiments of this kind are, however, not made at a temperature below ÷ 15° (Centigrade). At a still lower temperature there will presumably also at night turn out to be a difference, because the observer and his assistant will then proportionally give off more heat to the surrounding air.

During the summer of 1907 when I began some experiments, the object of which was to appraise the astronomical refraction, my attention was attracted towards the importance of the special refraction of the meridian aperture, and since then the temperature of the Observatory was measured by means of the dry thermometer in an Asmann aspiration psychrometer, which I borrowed from the expedition meteorologist. An apparatus of this kind is, however, not strictly necessary; if sufficiently careful one may make shift with an ordinary thermometer without an aspirator.

As an ephemeris and star catalogue we used the full edition of the Nautical Almanac. Experience showed, however, that it would have been well, had we supplied ourselves with a larger star catalogue.

Electric light. It appears from the above that small electric lamps were practically indispensable for the purpose of the winter work in the Observatory. These small lamps were, however, also used at the daily meteorological readings, for the observations to determine the conductivity and potential drop of the air, at the measuring of the Gnipa Cave and on several other occasions. Finally they were used to advantage on the sledge trips undertaken during the autumn and winter so as to get sufficient light for astronomical observations in the open air.

As far as is known there are no publications from former arctic expeditions treating of the use of electric light, and the material had consequently to be prepared at home on the basis of a rather rough estimate of the influence of the low temperature.

The electric light was based on the use of dry cells from the manufactory of Hellesens Enke & V. Ludvigsen, Copenhagen. Ten dry cells, type 0 Nr. 0, were calculated for use in the permanent lighting up of the Observatory, but besides we carried thirty-nine small cells, type 0 Nr. 7, of which the eighteen were collected in six small battery boxes in sets of three. The incandescent lamps were quite small carbon filament lamps, requiring a tension of about $4^1/_2$ volts and a current from $^1/_2$ to 1 ampère.

The electric light, which turned out to be so extremely valuable, was, on the other hand, the cause of many disappointments, because it failed so frequently. The cause of this has to this day never been explained fully.

The intensity of the light was often considerably diminished towards the end of a protracted series of observations, but was set right again, when battery and lamp were left for some time in a warm room. We were inclined to think that the diminution was mainly due to the cold, but unfortunately we could not investigate,

as we were not in possession of a voltmeter and an ampèremeter. This was indeed unfortunate, as a test of the cells would surely in most cases have shown that the disturbance was due to the bulb holder. Not until our second winter did we discover that the bulb holders were of such defective construction that the connection might easily become incomplete or fail altogether. Furthermore it turned out that rime often gathered on the contact surfaces of the switches, partly owing to the heat of the hand and partly to the air exhaled. The rime might act so powerfully as an insulating agent that the lamps became unfit for use, but when once our attention had been called to the rime, it was of course easy enough to guard ourselves against this inconvenience.

All our spare cells were during both winters kept stored in a shed, where they were exposed to a temperature as low as $\div 40°$ (Centigrade). They were now and then tested by means of an incandescent lamp, and they constantly proved to be undamaged[1]). I therefore do not doubt that the continued and frequent accidents which happened to our electric light must in the first place be attributed to the fact that we lacked the necessary practical knowledge. With a thorough practical insight as regards the lighting apparatus and its treatment we might easily have avoided most of the difficulties which we now never learned to surmount entirely.

To light up the Observatory in case of emergency we carried two ordinary kitchen lamps with reflectors. It is not advisable to use lamps of this kind in the Observatory, but one can make a couple of small windows there and place the lamps in little projections outside the window-panes. From the inside of the Observatory one must be able to keep out the light by means of a shutter or a heavy curtain. These emergency arrangements for lighting up the Observatory were never used.

During the latter half of August 1906 we decided to winter in Danmarks Havn (Harbour). The plan which had been arranged was to spend the autumn in getting an insight into the conditions, so that at the coming of spring we might begin to work according to a definite programme, but at the same time certain fundamental works had to he undertaken at once. In my own case the principal thing was to carry out a rough triangulation of the immediate surroundings of Danmarks Havn. In the course of the winter the

[1]) For the electric sparking of the motor car of the expedition we also used Hellesen's dry cells. Here they acted satisfactorily both summer and winter.

triangulation was then to be calculated so that a minute survey might be begun during the following summer.

The month of September was entirely taken up by triangulation and base measuring. On October 1st I went on a depot trip to Jøkelbugten (Glacier Bay), and not until after my return could I commence my work in the Observatory. On October 14th the first observations were made at a temperature of $\div 20°$ (Centigrade). From November 11th until December 4th I went on a sledge trip; after that I was at home at the station during the months of December and January, but on January 31st the depot trips in a northerly direction began, and so the observations in the Observatory wery practically at an end as far as that winter was concerned.

Consequently, having only had at our disposal the period from October 14th to November 10th as well at the months of December and January, it is not to be wondered at that the result of the observations during this winter was a very meagre one. However, we succeeded in determining the latitude and azimuth, as well as in making the necessary determinations of time, but otherwise the observations might rather be characterized as a series of exercises, in the course of which we gradually learned to surmount the rather considerable difficulties mentioned above and chiefly caused by the cold.

Taught by my experience during our first winter, I arranged things in such a manner as to be able to remain at the station during the months of September and October 1907 in order to be able to make use of the most favourable season in carrying out the comparatively difficult and protracted series of observations for the determination of the longitude (by azimuths of the moon).

During our first winter I had as my assistant Lieut. Hagen. After his death Dr. Wegener and Dr. Lindhard took up the work. The interest which these two men took in the observations, and the considerable practice which they, after a while, acquired as regards the practical carrying out of the observations as well as the calculation of same was extremely useful to me. Between them they made half of all the observations in the Observatory.

In the course of the preparations for the expedition Dr. Wegener had applied to Professor M. Schnauder, Observator at the Geodetic Institute of Potsdam, in order to be instructed in the purely practical arrangement of the observations. Professor Schnauder, out of pure interest for the cause, not only instructed Dr. Wegener in all the most important observation-methods, in particular observations of the moon with the attendant determinations of time, but also made the calculations of all of these tentative observations. In this manner

we came to possess a complete collection of examples of calculations for our guidance in Greenland, the value of which cannot be sufficiently appreciated. The Danmark-Ekspedition owes a great debt of gratitude to Professor SCHNAUDER for the considerable and disinterested work which he undertook on our behalf.

Determination of Azimuth.

The Observatory formed part of the triangulation net, being used as a station. In this manner it was made possible to carry out the determination of azimuth for the orientation of the triangulation net from the Observatory itself. Cairn V which was situated in a direction very nearly due south and at a distance of 16 km, could in this manner also serve as a meridian mark during the daytime, so that it was not always necessary to make a new azimuth observation to determine the meridian point of the horizontal circle, when the instrument, for some reason or other, had been removed from the pillar.

In determinations of azimuth we used the polar star. In latitudes as high as that of Danmarks Havn it is necessary to use the ocular prism in the case of observations of the polar star, because the zenith distance is so small. The observation of the star, therefore, requires a small a priori calculation, which may, however, be made quite roughly. For the below mentioned observation the a priori calculation has probably been confined to the following:

According to the sidereal chronometer the observation will take place at about $18^h\,30^m$; clock correction about $+\,1^h\,18^m$, thus sidereal time, θ, about 19^h48^m; hour angle $t = \theta \div \alpha =$ about $19^h\,48^m \div 1^h26^m$ = about $18^h.4$. During the observation the polar star will thus be very near its eastern elongation; its zenith distance must consequently be all but equal to the zenith distance of the Pole, thus for Danmarks Havn where the latitude $\varphi = 76°46'$, $z =$ about $13°.2$. This is sufficient. The finder is adjusted at $13°.2$, the telescope is by estimate directed into the vertical plane of the star, and it will then as a rule prove to be in the field or at any rate so near the latter that it is found immediately by carefully moving the instrument round the vertical axis.

In the following example thread No. 3 has not been used as a middle thread, but the polar star and the cairn are pointed right between threads No. 3 & 4. In this manner arises a collimation constant of about $^1/_2'$ (the interval between the threads is about $1'$), and this in its turn yields the very obvious difference of $5'$ in the readings of the polar star, corresponding to "telescope east" and "telescope west". For "telescope east" and "telescope west" we took, as

will be seen from the following, every time two observations of Polaris and one observation of Cairn V.

Azimuth by Polaris 5/IX 1907.

Correction of sidereal chronometer 57203 : $s = + 1^h18^m7^s$,

1 division of the level of the axis = 4".4.

Telescope	Polaris				Cairn V	
	57203	Microscope		Level	Microscope	
		1	2	W | E	1	2
E	*18h 23m 49s*	*216°55'.7*	*55'.5*	*15.2* | *5.0*	*210°03'.7*	*03'.4*
	26 04	*55 .7*	*55 .6*	*3.2* | *13.3*		
				3.0 | *13.2*		
				14.3 | *5.4*		
	18 24 57	216 55 .70	*55 .55*	+ 39.9 ÷ 32.7		
				+ 7.2 : 8 = + 0.90		
W	*30 58*	*37 00 .8*	*00 .3*	*3.5* | *13.6*	*30 03 .1*	*02 .8*
	33 25	*00 .7*	*00 .2*	*13.9* | *3.8*		
				14.0 | *3.9*		
				4.0 | *14.2*		
	18 32 12	37 00 .75	00 .25	+ 35.6 ÷ 35.3		
				+ 0.3 : 8 = + 0.04		
E	*37 18*	*216 55 .3*	*55 .4*	*15.1* | *5.0*	*210 03 .6*	*03 .5*
	39 10	*55 .3*	*55 .3*	*3.1* | *13.2*		
				3.1 | *13.2*		
				15.2 | *5.1*		
	18 38 14	216 55 .30	55 .35	+ 40.4 ÷ 32.6		
				+ 7.8 : 8 = + 0.98		
W	*43 42*	*37 00 .1*	*59 .8*	*3.9* | *14.0*	*30 03 .1*	*02 .8*
	45 28	*59 .9*	*59 .4*	*14.5* | *4.4*		
				14.5 | *4.4*		
				4.0 | *14.1*		
	18 44 35	36 60 .00	59 .60	+ 37.8 ÷ 36.0		
				+ 1.8 : 8 = + 0.34		

φ 76°46'16".9

δ 88 48 31 .6

α $1^h 26^m 14^s.3$

$i_1 + 4''.0$

$i_2 + 0\ .2$

$i_3 + 4\ .3$

$i_4 + 1\ .0$

$$\tan a = \frac{\div \cot \delta \sec \varphi \sin t}{1 \div \cot \delta \tan \varphi \cos t}$$

Level correction: $+ i \cot z$, where i is the elevation of the western end of the axis and where $\sin z = \div \sin t \cos \varphi$.

		1. observation		4. observation
$\log \sin t_n$		9.9988		9.9948
$- \cos \varphi$		9.3595		9.3595
$- \sin z$		9.3583		9.3543
$- \cot z$		0.6301		0.6343
$\log i_{1-4}$	0.6020	9.3010	0.6335	0.0000
$- i \cot z$	1.2321	9.9325	1.2664	0.6343

	E	W	E	W
Sidereal time θ	19 43 04	19 50 19	19 56 21	20 02 42
α	1 26 14	1 26 14	1 26 14	1 26 14
t	18 16 50	18 24 05	18 30 07	18 36 28
=	274°12′30″	276 01 15	277 31 45	279 07 00
Argument Albr. table 33[1]	7.812323	7.967461	8.064100	8.146605
$\log \tan \varphi$	0.628793	0.628793	0.628793	0.628793
$- \cos t$	8.865597	9.020735	9.117374	9.199879
$- \cot \delta$	8.317933	8.317933	8.317933	8.317933
Albrecht table 33[1]	+ 2828	+ 4048	+ 5063	+ 6116
$\log \sec \varphi$	0.640474	0.640474	0.640474	0.640474
$- \sin t$	9.998827_n	9.997598_n	9.996240_n	9.994479_n
$- \tan (\div \alpha)$	8.960062_n	8.960053_n	8.959710_n	8.959002_n
α	5°12′43″	5°12′42″	5°12′27″	5°11′57″
Horizontal readings	216 55 38	37 00 30	216 55 20″	36 59 48
Level correction	+ 17	+ 1	+ 19	+ 4
Meridian point	211 43 10	31 47 49	211 43 12	31 47 55
Cairn V, horizontal readings	210 03 33	30 02 57	210 03 33	30 02 57
Azimuth of Cairn V	÷ 1°39′37″	÷ 1°44′52″	÷ 1°39′39″	÷ 1°44′59″

Azimuth of Cairn V = ÷ 1°42′.3

[1]) Formeln und Hülfstafeln für geographische Ortsbestimmungen von Professor, Dr. Th Albrecht, Leipzig 1894.

A direct comparison of the results corresponding to "telescope east" or to "telescope west" shows that we might have been justified in giving the result in whole seconds; which fact we also intended to prove by means of the six-placed calculation. The scale microscopes of the horizontal circle, however, only permitted the estimating in tenths of minutes, and in this we find the principal source of the otherwise unimportant deviations within the same position of the telescope. If the instrument had been provided with ordinary reading microscopes for the horizontal circle, we might undoubtedly have carried our accuracy as far as seconds.

Determination of Time.

The object of the determinations of time was twofold; they partly served to render an account of time, generally speaking, and partly made a link in the determination of longitude. The former or more

general object necessitated the taking of observations for time at intervals during the whole year, and during the summer we could naturally do nothing but measure the zenith distance of the sun, whereas in the winter we almost exclusively used transits on the vertical of a circumpolar star near the Pole. On the other hand the transits on the meridian were only used on a few occasions for a purely preliminary determination of the clock correction, and the reason of this was first and foremost our lack of a meridian mark.

There is presumably no reason to occupy ourselves at greater length with the measurements of the zenith distance of the sun; they do not deviate in principle from the determinations of time by means of the sun, mentioned under the geographical survey, where also examples of computation are entered; only the computation becomes a little more elaborate here in consequence of the greater accuracy — tenths of a second — which in this case, at least from the point of view of computation, ought to be aimed at.

On the other hand I am going to enter into the determinations of time in the vertical of a polar star near the Pole; but before that I will give a short account of the comparison of the watches and the determination of the thread intervals.

Clock comparisons. Before and after the observations for time we made comparisons of the watches, partly in order to be able to control the rate of the observation watch during the observation, and partly to be able to transfer the exact time to the standard watch of the expedition, mean time chronometer 57310. Four comparisons were made in the course of a minute, as appears from the example quoted below.

The comparisons were made by two persons, each provided with a watch. The assistant announced "Ready" five seconds before the moment of comparison, and after that "Now"; the observer estimated the time corresponding to the moment of comparison on the observation watch in tenths of second.

Only very little practice is required to attain considerable skill in the estimating of the tenth of the second. By means of coincident beats of the mean time chronometer and the sidereal chronometer we might perhaps have carried the accuracy of comparison somewhat further; but, as will appear from the following, this would not have been of practical value to us. For the determination of the transit of a heavenly body we were besides obliged to use the same primitive method, as we had no chronograph with us.

Comparison of watches before and after the determination of time 24/IX 1907.

Before the observation.

57310 (mean time, standard watch)	*10h*	*25m*	*30s*	*45s*	*26m*	*00s*	*15s*
57203 (sidereal time, observation watch)	*21*	*18*	*55.3*	*10.3*	*25.3*		*40.4*
	÷10	53	25.3	25.3	25.3		25.4
57396 (sidereal time)	*22h*	*01m*	*15s*	*30s*	*45s*	*02m*	*00s*
57203 (sidereal time, observation watch)	*21*	*20*	*13.2*	*28.3*	*43.3*		*58.3*
	+41		01.8	01.7	01.7		01.7

After the observation

57310 (mean time, standard watch)	*11h*	*42m*	*30s*	*45s*	*43m*	*00s*	*15s*
57203 (sidereal time, observation watch)	*22*	*36*	*07.7*	*22.8*		*37.8*	*52.8*
	÷10	53	37.7	37.8	37.8		37.8
57396 (sidereal time)	*23h*	*18m*	*30s*	*45s*	*19m*	*00s*	*15s*
57203 (sidereal time, observation watch)	*22*	*37*	*28.3*	*43.3*	*58.3*		*13.2*
	+41		01.7	01.7	01.7		01.8

It appears that the observation watch kept its rate unchanged during the hour and a quarter which elapsed between the two comparisons, and in the course of which a determination of time as well as an observation of the occultation of a star has taken place.

The programme for the evening in question comprised an observation for time, an occultation of a fixed star by the moon, an observation for time, an azimuth of the moon (determination of longitude) and finally a finishing observation for time. The last-mentioned observation for time was abandoned on account of clouds.

The azimuth of the moon followed so closely upon the second determination of time that we could not find time to take the observation watch down to the "Villa" to make a comparison between the two observations. In the case of this group of observations the comparison shows:

Before the observation.

57310 (mean time, standard watch)	*12h*	*41m*	*30s*	*45s*	*42m*	*00s*	*15s*
57203 (sidereal time, observation watch)	*23*	*35*	*17.1*	*32.2*		*47.2*	*02.2*
	÷10	53	47.1	47.2	47.2		47.2
57396 (sidereal time)	*0h*	*17m*	*30s*	*45s*	*18m*	*00s*	*15s*
57203 (sidereal time, observation watch)	*23*	*36*	*28.2*	*43.2*		*58.2*	*13.2*
	+41		01.8	01.8	01.8		01.8

After the observation.

57310 (mean time, standard watch)	*14h*	*46m*	*00s*	*15s*	*30s*	*45s*
57203 (sidereal time, observation watch)	*1*	*40*	*06.7*	*21.7*	*36.8*	*51.9*
	÷10	54	06.7	06.7	06.8	06.9
57396 (sidereal time)	*2h*	*25m*	*00s*	*15s*	*30s*	*45s*
57203 (sidereal time, observation watch)	*1*	*43*	*57.9*	*12.8*	*27.7*	*42.8*
	+41		02.1	02.2	02.3	02.2

In this case the observation watch was apparently not able to stand the long exposure in the cold Observatory, but lost $0^s.4$ as compared with 57396. That it was really 57203 which altered its rate, appears doubly sure from the comparisons with the mean time watch, in that the relative rate of the two watches can be regarded as established on the basis of the first-mentioned comparisons on p. 105.

In the time which elapsed between $12^h41^m30^s$ and $14^h46^m00^s$ 57203, in comparison with 57310, should have gained $\frac{12^s.45}{77} \times 124.5 = 20^s.1$. However, it only gained $19^s.6$ as compared with 57310; the difference is $0^s.5$ which within the limit permissible corresponds with the above result.

The examples quoted, which are quite ordinary, show that we may with considerable certainty read off an ordinary good pocket watch in tenths of a second; and further, the last example shows how careful one must be as regards watch comparisons, before and after an observation has taken place.

Thread intervals. Before the commencement of the transit observations it was considered expedient to determine the thread intervals. As will appear from the example given below, which example is an extract of an observation group of twelve stars, we made use of stars with comparatively small declinations. The reason of this was that the thread intervals were determined during the latter part of August. The short nights were at that time still so light that stars of greater declination and of a suitable size were not visible. On the other hand the external conditions — light nights which made the use of artificial light superfluous; a temperature about zero — during the latter part of August and the beginning of September were particularly favourable. The meridian was pointed by directing the telescope for each position of the instrument against Cairn V, after which the instrument, by means of the graduation of the horizontal circle, was turned $1^\circ 42'.3$ to the right.

In the case of each single star the value of the thread intervals was computed for a star of a declination of zero ($\delta = 0$) according to the formula:

$$F^s = f^s \cos \delta$$

where F are the values corresponding to $\delta = 0$ whereas f are the thread intervals calculated in the column of differences in the observation table. As the ultimate values of the F's was used the mean of the single values (see p. 92). Of the thus determined F's the thread intervals were again calculated for stars having a declination of 1°, 2°, 3° . . . as far as 40°, and from the table thus procured the

Determination of thread intervals 31/VIII 1907 (extract)

Telescope east						Telescope west					
α Urs. maj. $\delta = 62° 15' 11''$			λ Draconis $\delta = 69° 50' 40''$			γ Cephei $\delta = 77° 06' 51''$			β Cassiopeiæ $\delta = 58° 38' 16''$		
Thread	57203	Diff.	Thread	57203	Diff.	Thread	57203	Diff.	Thread	57203	Diff.
1	21h39m19s.0	64s.6	1	22h6m46s.0	89s.2	6	22h16m02s.4	138s.6	6	22h45m53s.2	58s.6
2	50 .8	32 .8	2	7 29 .9	45 .3	5	17 11 .3	69 .7	5	46 22 .0	29 .8
3	40 23 .6	00 .0	3	8 15 .2	00 .0	4	18 04 .9	16 .1	4	44 .5	07 .3
4	32 .1	08 .5	4	25 .8	10 .6	3	21 .0	00 .0	3	51 .8	00 .0
5	57 .8	34 .2	5	9 00 .1	44 .9	2	19 29 .6	68 .6	2	47 21 .2	29 .4
6	41 29 .8	66 .2	6	44 .0	88 .8	1	20 37 .1	136 .1	1	50 .3	58 .5

thread intervals which at a given moment were required were taken by interpolation. They were computed in hundreds of a second.

As the thread intervals are computed for the meridian transit, they do not hold good for transits outside it. For transits on the vertical of the polar star, this is of no practical importance (a few hundreds of a second). If one sees fit, however, one may easily compute the correction for the deviation from the meridian by using, as an argument at the interpolation, a fictitious declination $[\delta]$ determined by $\sec [\delta] = \sec \delta \sec a$, where a is the azimuth in which the transit is observed.

The principle for the determination of time in the vertical of a polar star is, briefly speaking, that a star near the Pole is used as a sort of meridian mark. In the vertical of this star corresponding to certain sharply indicated moments, the transits of an equal number of stars are observed e. g. two to three with "telescope east" and an equal number with "telescope west". The method thus demands that the azimuth in the case of the pole star and the immediately succeeding equatorial star should be identical, in other words, the pole star being pointed (on the middle thread) the clamp and slow motion screw ot the horizontal circle must not be touched before the transit of the corresponding equatorial star. As the inclination of the axis, particularly in high latitudes, plays a great part as regards the accuracy of the determination for time (the level correction is $\div i \sec \varphi$) and as it is further particularly difficult in a low temperature, as mentioned on pp. 93—94 to determine the latter, great care must be exercised in the level observations.

In order to be able to direct the telescope towards a star quickly and unfailingly, it was necessary to have tables for the rough computation of the azimuth of the pole star and the corresponding

hour angle of the equatorial star. In Albrecht's collection of tables there are tables of this kind, but as they were only computed for latitudes as far as the 64th parallel, we had to make a special table for Danmarks Havn.

The azimuth table was computed for every 10′ of the hour angle by the formula;

$$A = [\div (90° \div \delta_0) \sin t \div {}^1/_2 (90° \div \delta_0)^2 \sin 1' \tan \varphi \sin 2\, t] \sec \varphi$$

where δ_0 was a roughly estimated and rounded off mean value, 88° 49′ 00″, for the declination of Polaris in the years 1906—07. The table indicated A in tenths of a minute.

As the azimuth corresponding to the declination δ' is

$$a_n = A \frac{90° \div \delta'}{90° \div \delta_0}$$

we further made a small table for every 10″ for the factor $\frac{90° \div \delta'}{90° \div \delta_0}$ (3 decimals). For the hour angle of the equatorial star one has approximately

$$t^s = 4 \frac{\sin (\varphi \div \delta)}{\cos \delta} a.$$

The table of the factor $4 \frac{\sin (\varphi \div \delta)}{\cos \delta}$ was computed to two decimals for every whole degree of the declination from 0° to 40°. In case such a table is to be used for the abbreviated method for calculation of observations for time mentioned on pp. 116—117 it ought, however, to be computed to three decimals.

The hour angle being known, the zenith distance of Polaris could be estimated with great certainty, and consequently a special table of this (Albrecht table 5) was not necessary. Neither had we any use for the table of the zenith distance of the equatorial star; the value corresponding to the meridian being sufficient. However, as it turned out to be practical to make out from the star catalogue a special list of equatorial stars with a northern declination from 0°—40° (magnitude and right ascension), $z = \varphi \div \delta$ was naturally put down instead of δ.

As an example I will go through the two determinations for time made on 24 IX 1907. Out of the above mentioned list of equatorial stars of a northern declination from 0°—40° the following two groups were selected:

Star	Mag.	α	z	Star	Mag.	α	z
η Pegasi	3.1	22h38m38s	47°03′	β Arietis	2.7	1h49m29s	56°25′
μ Pegasi	3.7	22 45 30	52 40	α Arietis	2.2	2 01 55	53 45
γ Piscium	3.8	23 12 20	74 00	ξ^1 Ceti	4.5	2 08 03	68 22
$\varkappa$ Piscium	5.0	23 22 09	76 02	ξ^2 Ceti	4.3	2 23 12	68 44

The smallest interval between two succeeding transits is here about 7^m. A smaller interval than 5^m ought to be avoided under the difficult arctic conditions. It further appears that the stars have been selected on the principle that two and two make pairs with nearly the same zenith distance. In this manner the collimation constant is prevented from exercising any noticeable influence.

It will generally be sufficient to carry on the preliminary computation for the first and the last star of a group; for the transit of the interjacent stars the azimuth of Polaris and the hour angles of the equatorial stars may be estimated. As an example I shall here perform the preliminary computation for the former of the two above-mentioned groups.

The approximated correction of the sidereal clock 57203 is $du = +1^h19^m.6$. — The right ascension of Polaris is $\alpha = 1^h26^m49^s$ its declination $\delta' = 88°48'38''$. As the first approximation we may consider the sidereal time for the transit of an equatorial star as equal to its right ascension. The corresponding values for the hour angle of Polaris then become:

for η Pegasi, $t_1 = 22^h38^m38^s \div 1^h26^m49^s =$ about 21^h12^m,
for $\varkappa$ Piscium, $t_4 = 23^h22^m09^s \div 1^h26^m49^s =$ about 21^h55^m.

With these values as an argument the azimuth of Polaris is taken from the tables corresponding to the above-mentioned formula

$$a_n = A \frac{90° \div \delta'}{90° \div \delta_0},$$ which makes $a_n{}^1 = +222'.9$, $a_n{}^4 = +174',6$.

For the hour angles of the equatorial star we have $t = a \frac{4 \sin (\varphi \div \delta)}{\cos \delta}$ where the factor $\frac{4 \sin (\varphi \div \delta)}{\cos \delta}$ is taken from the above-mentioned table corresponding to the arguments $\delta_1 = 29°.7$ and $\delta_4 = 0°.7$. In this manner we arrive at

$$t_1 = +12^m29^s \text{ and } t_4 = +11^m17^s$$

The clock times for the transit of η Pegasi and $\varkappa$ Piscium would consequently be:

$U_1 = +22^h38^m38^s + 12^m29^s \div 1^h19^m.6 =$ about $21^h31^m.5$ and
$U_4 = +23^h22^m09^s + 11^m17^s \div 1^h19^m.6 =$ about $22^h13^m.8$.

If we compare the moments of transit calculated a priori with the result of the observations quoted below, it will appear that the transit moments observed (the mean of all the threads) are $21^h30^m.9$ and $22^h13^m.3$ respectively. The supposed clock correction $du = +1^h19^m.6$ is the right one, and the deviations are simply due to the

circumstance that as our first approximation we considered the time of the transit as being equal to the right ascensions of the corresponding stars, that is, we assumed that the hour angles of the equatorial stars at the moment of transit was zero. Now, however, the preliminary computation proves

$$t_1 = +12^m29^s \text{ and } t_4 = +11^m17^s.$$

We might thus have made a fresh computation with the values:

$$t^1 = 22^h38^m38^s + 12^m29^s \div 1^h26^m49^s = \text{about } 21^h24^m \text{ and}$$
$$t^4 = 23^h22^m09^s + 11^m17^s \div 1^h26^m49^s = \text{about } 22^h07^m$$

and the moments of transit calculated in this manner would then have been identical with those observed. A fresh computation of this kind is, however, superfluous; even a difference of a whole minute between the time of transit calculated a priori and the one observed offers no practical difficulties.

To the preliminary computation further belongs an estimate of the readings of the horizontal circle corresponding to the various observations of Polaris. As we had no meridian mark, the meridian point of the circle had to be known within a few minutes. By means of this and the values for a^1 and a^4 found in the course of the preliminary computation we computed the reading of the corresponding divisions of the horizontal circle. As regards the other two observations of Polaris we simply estimated in the course of the observation itself.

Before mentioning the method of observation the contents of the observation journal will be quoted as regards the former star group, i. e. 1) the result of the preliminary computations, 2) the observations themselves, and 3) the calculations made in the observation journal.

Determination for time 24/XI 1907.

Observer: Koch; Assistant: Wegener.

	Mag.	57203	z	Horizontal circle
Polaris	2.1	21h25m	12°.8	35°13′
η Pegasi	3.1	21 31.5	47 .1	
μ Pegasi	3.7	21 38.5	52 .7	
γ Piscium	3.8	22 04.5	74 .0	
$\varkappa$ Piscium	5.0	22 13,8	76 .0	34°25′

Telesc.	57203	Level W	Level E	Level calculation
E	*Polaris*	*4.2*	*15.4*	÷ 0.73
	21h29m04s	*13.9*	*2.8*	÷ 1.08
	η Pegasi	*12.8*	*1.7*	÷ 1.43
		4.5	*15.7*	
	21 30 19.7	21	30	54.76
	37.0			54.68
	55.0			55.00
	59.2			54.92
	31 12.9			54.93
	30.1			54.73
	mean	21	30	54.84
W	*Polaris*	*15.1*	*4.0*	+ 0.85
	21 35 43	*2.2*	*13.5*	+ 1.10
		1.8	*12.9*	+ 1.35
	μ Pegasi	*15.5*	*4.6*	
	21 37 28.6	21	38	2.25
	45.0			2.09
	58.1			1.98
	38 02.1			2.10
	18.9			2.08
	35.3			1.94
	mean	21	38	02.07

Telesc.	57203	Level W	Level E	Level calculation
W	*Polaris*	*15.9*	*4.9*	+ 0.90
	21h57m26s	*3.1*	*14.1*	+ 0.89
	γ Piscium	*2.9*	*13.8*	+ 0.88
		15.1	*5.1*	
	22 04 01.8	22	04	32.55
	17.2			32.82
	29.0			32.72
	32.9			32.90
	47.7			32.33
	05 03.7			33.21
	mean	22	04	32.76
E	*Polaris*	*4.3*	*15.3*	÷ 0.58
	22 08 10	*14.2*	*3.1*	÷ 0.89
		13.5	*2.5*	÷ 1.20
	x Piscium	*4.9*	*15.9*	
	22 12 47.0	22	13	17.45
	13 02.4			17.75
	17.9			17.90
	21.5			17.78
	33.3			17.70
	48.8			18.09
	mean	22	13	17.78

The carrying out of the observation is as follows:

1. About an hour before the observation the instrument is made ready. Everything of the nature of grease is wiped off the pivots and the V's with spirit; the verification of the instrument is tested.

2. Comparison of watches. The watch used for observations is taken into the open air and placed in a glass bowl with a closely fitting cover (see pp. 96—97).

3. The observer goes to the Observatory a couple of minutes before the beginning of the observation.

a. Polaris is observed on the middle thread. The watch is read off. The striding level is read off, reversed and read off once more. Whenever the level is reversed, the feet of the latter are wiped with a piece of chamois leather.

b. The clamp of the vertical circle is loosened — care must be taken not to touch the clamp and the slow moving screw of the horizontal circle — and the telescope is directed towards the previously computed zenith distance of the equatorial star (for η Pegasi here 47°.1). The vertical circle is clamped.

When the equatorial star appears within the field, the direction of the telescope in altitude is improved with the slow moving screw,

so that the star is made to pass fairly through the centre of the field, without, however, moving along a horizontal thread.

The level may now be read off and reversed.

About five seconds before the appearance of the star on each thread the observer announces "Ready" and then "Now", when the star crosses the thread. The assistant notes the transit from the watch.

The level is read off, perhaps read off, reversed and read off.

c. The universal instrument is reversed. Second observation of Polaris.

Otherwise the operations mentioned above are now repeated with every succeeding transit.

4. Comparison of watches.

5. After the conclusion of the observations of the evening, the instrument is greased and covered.

Notes as regards the computation made in the observation table.

The level should indicate the elevation of the western end in level divisions. It appears that the inclination of the axis has been rather different in the case of Polaris and the equatorial star, which is possibly to some extent due to a slight flexure of the axis. When fixing the level correction it is, however, taken for granted that the inclination of the axis is the same in the case of Polaris and the equatorial star and equal to the mean of the two values.

The reduction to middle thread might have been omitted in the example quoted, because here where all transits across all threads have been observed, it has no influence on the ultimate result. It should, however, always be done, because in that manner one gets a direct and very good idea of the accurracy with which the transits have been observed. As regards the reduction to middle thread see further pp. 92 and 106—107.

Besides the observation mentioned above there was made one more determination for time on the same evening. The latter was as follows:

Determination for time 24/IX 1907.

Observer: Koch; Assistant: Wegener.

	Mag.	57203	z	Horizontal circle
Polaris	2.1	0^h23^m	12°	31°13′
β Arietis	2.7	0 28.0	56 .4	
α Arietis	2 2	0 39.5	53 .8	
ξ^1 Ceti	4.5	0 45.1	68 .4	
ξ^2 Ceti	4.3	0 58.8	68 .7	30°25′

Telesc.	57203	Level W	Level E	Level calculation	Telesc.	57202	Level W	Level E	Level calculation
E	*Polaris*	*3.5*	*14.8*	+ 0.25	W	*Polaris*	*15.8*	*4.6*	+ 0.90
	$0^h23^m29^s$	*15.3*	*4.0*	÷ 0.04		$0^h42^m34^s$	*2.8*	*14.0*	+ 1.00
	β Arietis	*14.8*	*3.6*	÷ 0.33		*ξ¹ Ceti*	*2.5*	*13.8*	+ 1.10
		4.2	*15.5*				*16.0*	*4.7*	
	0 27 48.9	0	28	21.37		*0 44 50.9*	0	45	21.95
	28 04.8			21.17		*45 06.1*			21.87
	21.0			21.00		*18.1*			21.86
	25.0			21.03		*22.0*			22.00
	37.6			20.97		*37.2*			21.68
	54.0			21.25		*52.9*			22.12
	mean	0	28	21.13		mean	0	45	21.91
W	*Polaris*	*14.8*	*3.5*	+ 0.05	E	*Polaris*	*4.5*	*15.8*	÷ 0.80
	0 32 09	*3.4*	*14.7*	+ 0.43		*0 53 43*	*14.2*	*2.9*	÷ 1.10
		2.8	*14.0*	+ 0.80			*13.2*	*2.0*	÷ 1.40
	α Arietis	*15.7*	*4.3*			*ξ² Ceti*	*4.8*	*16.0*	
	0 39 47.0	0	40	20.37		*0 58 40.7*	0	59	11.45
	40 03.4			20.35		*56.0*			11.50
	16.1			20.14		*59 11.3*			11.30
	20.0			20.00		*15.2*			11.44
	37.1			20.42		*27.2*			11.45
	53.6			20.51		*42.7*			11.69
	mean	0	40	20.30		mean	0	59	11.47

The computation below of the two determinations for time has been made according to the formulæ:

$$t' \div t = (U' \div \alpha') \div (U \div \alpha),$$

$$\tan x = \frac{\tan \delta \cot \delta' \sin (t' \div t)}{1 \div \tan \delta \cot \delta' \cos (t' \div t)},$$

$$\sin m = \tan \varphi \cot \delta \sin x,$$

$$du = \alpha \div U + \frac{x \div m}{15} \div i \sec \varphi \pm c \sec \varphi \frac{\cos {}^1/_2 (z' \div z)}{\cos {}^1/_2 (z' + z)} \begin{cases} \text{Telesc. east} \\ \text{Telesc. west} \end{cases}$$

Here i is the elevation of the western end of the axis; c is the collimation constant. A division of the level $p = 4''.45$; $\log \tan \varphi = 0.62878$; ${}^1/_{15}\, p \sec \varphi = 1^s.30$; $c = \div\ 1^s.85$. At the calculation of $\tan x$ we made use of Albrecht's auxiliary table 33.

The single values for du here coincide very well and yield a mean error of the medium of less than $0^s.5$. Still one should generally not assign a value of less than about 1^s to this mean error as also indicated by the other observations.

The following computation is made out in all details. We have generally avoided computing the term $c \sec \varphi \frac{\cos \frac{1}{2} (z' \div z)}{\cos \frac{1}{2} (z' + z)}$ which very nearly becomes equally great towards east and west, and only has

α Urs. min. 24/IX 1907.

Star	η *Pegasi*	μ *Pegasi*	γ *Piscium*	$\varkappa$ *Piscium*	β *Arietis*	α *Arietis*	ξ^1 *Ceti*	ξ^2 *Ceti*
Telesc. and level	E ÷ 1.08	W + 1.10	W − 0.89	E ÷ 0.89	E ÷ 0.8	W + 0.43	W + 1.00	E ÷ 1.10
U / α' / δ' Polaris	21h29m04s / 1 26 49 / 88°48′ 38″	21h35m43s / 1 26 49 / 88°48′ 38″	21h57m26s / 1 26 49 / 88°48′ 38″	22h08m10s / 1 26 49 / 88°48′ 38″	24h23m29s / 1 26 49 / 88°48′ 38″	0h32m09s / 1 26 49 / 88°48′ 38″	0h42m34s / 1 26 49 / 88°48′ 38″	0h53m43s / 1 26 49 / 88°48′ 38″
U / α / δ Fixed star	21h30m54s.84 / 22 38 41.03 / 29°44′ 23″	21h38m02s.07 / 22 45 33.34 / 24°06′ 56″	22h04m32s.76 / 23 12 23.13 / 2°46′ 43″	22h13m17s.78 / 23 22 12.37 / 0°45′ 04″	(0h28m21s.1 / 1 49 32.5 / 20°21′ 24″	0h40m20s.30 / 2 01 58.27 / 23°01′ 32″	0h45m21s.91 / 2 08 06.52 / 8°24′ 50″	0h59m11s.47 / 2 23 15.08 / 8°02′ 48″
$t' = U \div \alpha'$	20h02m15s	20h08m54s	20h30m37s	20h41m21s	22h56m40s	23h05m20s	23h15m45s	23h26m54s
$\div t = \div (U \div \alpha)$	1 07 46	1 07 31	1 07 50	1 08 55	1 21 11	1 21 38	1 22 45	1 24 04
$t' \div t$ (time)	21 10 01	21 16 25	21 38 27	21 50 16	0 17 51	0 26 58	0 38 30	0 50 58
$t' \div t$ (degrees)	317°30′ 15″	319°06′ 15″	324°36′ 45″	327°34′ 00″	4°27′ 45″	6°44′ 30″	9°37′ 30″	12°44′ 30″
Argument Albrecht 33	7.94180	7.84668	6.91462	6.36123	7.88537	7.94264	7.48112	7.45681
log cos $(t' \div t)$	9.86766	9.87847	9.91130	9.92635	9.99868	9.99698	9.99384	9.98918
log tan δ	9.75687	9.65094	8.68605	8.11761	9.56942	9.62839	9.17001	9.15036
log cot δ'	8.31727	8.31727	8.31727	8.31727	8.31727	8.31727	8.31727	8.31727
log sin $(t' \div t)$	9.82965 n	9.81603 n	9.76275 n	9.72942 n	8.89234	9.06965	9.22324	9.34352
Albrecht 33	+ 382	306	36	10	335	382	132	125
log tan x	7.90761 n	7.78730 n	6.76643 n	6.16440 n	6.78238	7.01913	6.71184	6.81240
log cot δ	0.24313	0.34906	1.31395	1.88239	0.43058	0.37161	0.82999	0.84964
log sin x	7.90760 n	7.78730 n	6.76643 n	6.16440 n	6.73238	7.01913	6.71184	6.81240
log sin m	8.77951 n	8.76514 n	8.70916 n	8.67557 n	7.84174	8.01952	8.17061	8.29082
x	÷ 27′ 47″	÷ 21′ 04″	÷ 2′ 00″	÷ 0′ 30″	2′ 05″	3′ 36″	1′ 46″	2′ 14″
$\div m$	+ 3°27′ 02	+ 3°20′ 18	÷ 2°56′ 03	+ 2°42′ 56	÷ 0°23′ 53	÷ 0°35′ 58	÷ 0°50′ 55	÷ 1°07′ 10
$x \div m$	+ 2 59 15	+ 2 59 14	+ 2 54 03	+ 2 42 26	÷ 0 21 48	÷ 0 32 22	÷ 0 49 09	÷ 1 04 56
$(x \div m) : 15$	0h11m57s.00	0h11m56s.93	0h11m36s.20	0h10m49s.73	÷ 0h01m27s.2	÷ 0h02m09s.47	÷ 0h03m16s.60	÷ 0h04m19s.73
$\alpha \div U$	1 07 46.19	1 07 31.27	1 07 50.37	1 08 54.59	1 21 11.42	1 21 37.97	1 22 44.61	1 21 03.61
$\div i \sec \varphi$	+ 1.40	÷ 1.43	÷ 1.16	+ 1.16	+ 0.05	÷ 0.56	÷ 1.30	+ 1.43
$\mp c \sec \varphi \frac{\cos \frac{1}{2}(z' \div z)}{\cos \frac{1}{2}(z' + z)}$	÷ 8.91	+ 9.05	+ 9.55	÷ 9.61	÷ 9.05	+ 8.98	+ 9.30	÷ 9.34
du	1 19 35.68	1 19 35.82	1 19 34.96	1 19 35.87	1 19 35.20	1 19 36.92	1 19 36.01	1 19 35.97
Mean of du	+ 1h19m35s.58					+ 1h19m36s.03		
at clock time	21m51m.6					0h43m.3		
Hourly rate	+ 0s.16							

different signs. This facilitation is not only permissible in the light of the accuracy arrived at, but still more so in the light of the fact that the collimation was rather changeable and consequently had to be computed every time by means of the observations. This being so the computation of the collimation would only lead to a false idea arising as to the accuracy of the observation.

The rather circumstantial computations which the determination for time in the vertical of the pole star requires have, as a rule, a rather deterrent effect on the non-professional. One must, however, not overlook the fact that a large percentage of the computations mentioned above refer to the making of certain auxiliary tables, in other words, a work which is done once for all. The computation of an observation of four transits is scarcely more circumstantial than that of a group of twelve zenith distances.

The matter is more complicated than the ordinary measuring of the zenith distance and offers more technical difficulties, but it is in its turn more reliable, being independent of the largely varying refraction which occurs in arctic regions. If when measuring the zenith distance one tries to guard oneself against the influence of the refraction by observing two stars, one in the east and one in the west, this method loses a good deal of its attractive simplicity, while at the same time the computation work is nearly doubled.

Whether electing to employ the one method or the other, one ought to be provided with a large star catalogue. The Danmark-Ekspedition only had at its disposal the star catalogue in the full

edition of the Nautical Almanac, and we had consequently great difficulty in finding suitable stars for the determinations for time. In order to prevent the determinations for time and the moon observations from clashing we often had recourse to λ Urs. min. as a pole star instead of α Urs. min. The former star is nearer the Pole than Polaris, and besides it has the advantage of being only 6.6 in magnitude, which facilitates an accurate pointing.

In order to avoid the rather circumstantial computation of the determination for time on the vertical of Polaris, several methods for an abbreviated calculation have been set up, which methods, however, either do not represent any noticeable lessening of labour or become tantamount to a considerably less degree of accuracy. The latter circumstance would, however, be of no importance, if only the accuracy of computation corresponded to the accuracy of observation.

An abbreviated form of computation which we used from time to time is the following:

By means of the clock time U' for the pointing of Polaris and the approximate clock correction du_0, the azimuth of Polaris a'_n was taken from the table mentioned in the preliminary computation (argument: The hour angle of Polaris t'). By means of the above mentioned table for the factor $4\frac{\sin\,(\varphi \div \delta)}{\cos\,\delta}$ the hour angle of the equatorial star t is computed, after which the sidereal time $= \alpha + t$ is determined. Result:

$$du = \alpha + t \div (U + i \sec \varphi).$$

As an example the two above-mentioned determinations for time will be computed according to the abbreviated manner of computation here mentioned. The clock correction is approximately estimated $du_0 = + 1^h\,19^m\,30^s$; this makes:

$$U'_0 = a' \div du_0 = 1^h\,26^m\,49^s \div 1^h\,19^m\,30^s = + 7^m\,19^s.$$

In this case there is no question of applying the correction for collimation.

If a comparison is made with the values of clock corrections, arrived at by means of the earlier computation, it appears that the errors resulting from the abbreviated computation are of $0^s.2$ and $0^s.9$ respectively. A rough estimate will show that the chief reason for this is to be found in the error of the approximated clock value du_0.

The example shows that it would not generally have been permissible to adopt this abbreviated manner in the case of the determinations for time of the Danmark-Ekspedition.

α Urs. min. 24/IX 1907.

Star	η *Pegasi*	μ *Pegasi*	γ *Piscium*	$\varkappa$ *Piscium*	β *Arietis*	α *Arietis*	ξ^1 *Ceti*	ξ^2 *Ceti*
Telesc. and level	E $\div 1.08$	W $+1.10$	W $+0.89$	E $\div 0.89$	E $\div 0.04$	W $+0.43$	W $+1.00$	E $\div 1.10$
δ	29°44′.4	29°06′.9	2°46′.7	0°45′.1	20°21′.4	23°01′.5	8°24′.8	8°02′.8
$4\frac{\sin(\varphi \div \delta)}{\cos\delta}$	3.371	3.484	3.849	3.882	3.554	3.505	3.759	3.765
U'	21h29m04s	21h35m43s	21h57m26s	22h08m10s	0h23m29s	0h32m09s	0h42m34s	0h53m43s
$t' = U' \div U'_o$	21 21 45	21 28 24	21 50 07	22 00 51	0 16 10	0 24 50	0 35 15	0 46 24
a'_n	$+212'.7$	$+205'.5$	$+180'.7$	$+167'.5$	$\div 24'.2$	$\div 37'.0$	$\div 52'.4$	$\div 68'.5$
$t = a'_n \frac{4\sin(\varphi \div \delta)}{\cos\delta}$	+ 11m57s.0	+ 11m56s.0	+ 11m36s.0	+ 10m50s.2	$\div$ 10m26s.2	$\div$ 2m09s.7	$\div$ 3m17s.0	$\div$ 4m17s.9
α	22 38 41.0	22 45 33.3	23 12 23.1	23 22 12.4	1 49 32.6	2 01 58.3	2 08 06.5	2 23 15.1
Sidereal time	22 50 38.0	22 57 29.3	23 23 59.1	23 33 02.6	1 48 06.6	1 59 48.6	2 04 49.5	2 18 57.2
U	21 30 54.8	21 38 02.1	22 04 32.8	22 13 17.8	0 28 21.1	0 40 20.3	0 45 21.9	0 59 11.5
$i \sec\varphi$	$\div 1.4$	$+1.4$	$+1.2$	$\div 1.2$	$\div 0.1$	$+0.6$	$+1.3$	$\div 1.4$
du	+ 1 19 44.6	+ 1 19 25.8	+ 1 19 25.1	+ 1 19 46.0	+ 1 19 46.6	+ 1 19 27.7	+ 1 19 26.3	+ 1 19 47.1
Mean	+ 1h19m35s.4				+ 1h 19m36s.9			

As suggested on several occasions, the keeping of a fully satisfactory constant rate, especially as regards the observation watch, caused insurmountable difficulties. In order to illustrate this, I shall give below a summary of the rates of the observation watch on the days, when the moon observations were made for the determination of the longitude. This survey shows great oscillations, and this is particularly obvious in cases where two determinations of the clock rate were made on the same day (22/XI and 23/XI). From this it appears that the observation watch, in spite of all the precautions taken, was not able to stand exposure to low temperature for any length of time.

24. Sept.	hourly rate	+ 0^s.16
25. —	—	0.00
18. Oct.	—	+ 0.12
19. —	—	÷ 0.04
20. —	—	+ 0.32
22. —	—	÷ 0.18
28. —	—	+ 0.21
29. —	—	+ 0.33
17. Nov.	—	+ 0.01
22. —	—	+ 0.51
— —	—	+ 0.22
23. —	—	+ 0.01
— —	—	+ 0.40
24. —	—	+ 0.12
25. —	—	+ 0.21

Determinations of Longitude.

For the determinations of longitude we used transits of the moon and an adjacent star, with the telescope unchanged in azimuthal direction.

The principle of the determination is the following: By means of the time of the transit of the moon, of its declination and the latitude of the place in question, the azimuth of the moon is computed. The same method is used as regards the star, and the azimuthal direction of the telescope being unchanged one must — apart from errors of observation — arrive at the same azimuthal value in the case of both celestial bodies. It is, however, a presupposition that the exact value of the right ascension of the moon is known, which in its turn presupposes a knowledge of the longitude of the place. The latter, which is the value looked for, is only known approximately; the right ascension and consequently the moon

azimuth thus become subject to a certain error, and the harmony with the azimuth computed by means of the star observation, which may be regarded as infallible, is rendered incomplete. The deviation of the two azimuths seems to suggest the correction of the supposed value of the longitude of the place.

Preparation for the observations.

Let us fix the approximated length at l_0. Corresponding to the latter and based upon the data given in the Nautical Almanac under Moon-Culminating Stars, for Moon I or II *U*(pper) and for the Var. of ☾'s R. A. and Decl. in one hour of Long. an approximated right ascension of the bright limb and an approximated geocentric declination of the centre of the moon are computed with an accuracy of about $0^m.1$ and $1'$ for the culmination at the place of observation.

From Apparent Places of Stars, Moon-Culminating Stars (preferably) or Occultation Stars a star is selected, the right ascension and declination of which approach as nearly as possible to the right ascension and declination of the moon. (In certain cases it is not

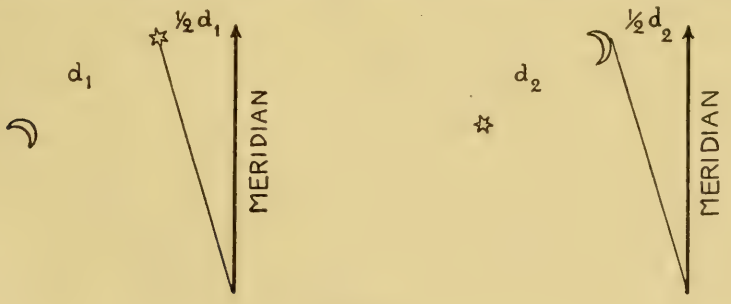


Fig. 5.

possible to reduce the right ascension difference to less than 15^m to 20^m; it must not be less than 2^m, as in that case one cannot escape the clashing of the moon and star observations).

In order to arrange the two observation sets — "telescope east" and "telescope west" — as symetrically as possible as regards the meridian one puts (Fig. 5)

when the star appears first ($\alpha * < \alpha ☾$): $\alpha ☾ \div \alpha * = d_1$,
when tbe star appears last ($\alpha * > \alpha ☾$): $\alpha * \div \alpha ☾ = d_2$.

The clock correction being *du*, $U_0 = \alpha * \div du$ becomes clock time for the culmination of the star. The object which is the flrst to appear is then to be observed in the first position of the instrument at the clock time $U_0 \div {}^1/_2\, d_1$, respectively $U_0 \div {}^3/_2\, d_2$ east of the meridian.

However, in order to gain time for the reading off of the level of the axis and to reverse the universal instrument, as well as to direct the telescope in the new position of the instrument west of the meridian and to make allowance for the change of the right ascension of the moon during the observation (the right ascension is smallest prior to the culmination), and also for the somewhat altered declination of the moon the clock times given must be reduced by about 3^m, whereby about 6^m are gained for the second position of the instrument. Corresponding to the hour angle $^1/_2\, d_1 + 3^m$, respectively $^1/_2\, d_2 + 3^m$ we must then compute approximately:

for the star: azimuth and zenith distance
for the moon: zenith distance

in which manner we become able to bring the instrument into position for the observation.

For the moon it is sufficient when computing the zenith distance to use a mean value of the parallax of about 50′. The reduction to meridian and the refraction, which partly compensate each other, are left out. φ being the geographical latitude we consequently get

$$z\,\mathbb{C} = \varphi \div \delta\,\mathbb{C} + 50',$$
$$z\,* = \varphi \div \delta\,* \text{ and}$$
$$\sin a\,* = \frac{\sin\,(^1/_2\, d + 3^m)\,\cos \delta\,*}{\sin\ z\,*} \text{ (four-placed).}$$

When two stars have to be connected with the moon (before and after the moon, that is $a_1\,* < a\,\mathbb{C} < a_2\,*$) the hour angle under which the stars are to be observed is approximately

$$\begin{matrix}\div \\ +\end{matrix}\left(\frac{a_2\,* \div a_1\,*}{2} + 3^m\right) \begin{matrix}\text{before} \\ \text{after}\end{matrix}\Big\} \text{ the meridian.}$$

The azimuth is then to be computed from the mean of the declinations.

Before the culmination we thus get the most southerly star and after the culmination the most northerly one in the pointed azimuth somewhat earlier than indicated by the computed time.

The carrying out of the observation. *M. P.* being the meridian point of the horizontal circle and *Z. P.* the zenith point of the vertical circle, the horizontal reading becomes in the case of the observation east of the meridian $M.\,P. \div a*$, while the one west of the meridian becomes $M.\,P. + a*$. According to the position of the instrument the vertical circle is placed at $Z.\,P. \pm z$, where z is the zenith distance computed for the object which appears first. Within each observation set the azimuth must not be changed.

$1^1/_2{}^m$ to 2^m before the clock time of the transit computed for the object, which appears first, the level of the axis is read off and reversed. 1^m at the latest before the time calculated the observer has to be ready at the ocular pointing the object by means of the slow moving screw of the vertical circle. The transit is observed; the level is read off; the clamp of the vertical circle is loosened; the telescope is placed at the zenith distance of the next object, and the observation of the latter is carried out in exactly the same manner as in the case of the first object. After the last reading of the level the universal instrument is reversed, the horizontal circle is placed on *M. P.* $+ a*$ and set II is performed quite analogously with set I.

Determinations for time before and after the observation are necessary.

As an example of the determination of longitude by means of the moon azimuth I shall quote in detail the observation of 25/IX 1907.

Preliminary computation:

$l_0 = +1^h15^m$; $\varphi = 76°46'.3$; du = about $+1^h19^m.6$.

Grw. culmination of limb II.

	α	Var. 1^h Long.	δ	Var. 1^h Long.
25/IX ☾ II *L*(ower).....	$3^h08^m09^s$	129^s	$+12°52'.6$	$618''$
— *f Tauri*.....	3 25 46		12 37.2	$\div 59''$
— ☾ II *U*(pper).....	3 33 53	129	14 50.4	559
26/IX ☾ II *L*.....	3 59 44	130	16 36.0	496 $\div 63''$

$$\Delta\delta\,☾ = 559'' \div \frac{59'' + 63''}{24} \cdot \frac{l_0}{2} = 559'' \div \frac{122''}{24} \cdot \frac{5}{8} = 556''$$

α ☾ Grw. $3^h33^m53^s$	δ ☾ Grw. ..... $14°50'.4$
var. $129^s \cdot 1^1/_4 = +2\ 41$	var. $556'' \cdot 1^1/_4$ .. $+11.6$
α ☾ ..... $3^h36^m34^s$	δ ☾ ..... $15°02'.0$
	$\varphi \div \delta$ ☾ 61 44.3
	Parallax..... $+50$
	z ☾ ..... $62°34'$; $\varphi \div \delta * = z * = 64°09'.1$

α ☾ $\div \alpha * = d_1$.....	$10^m.8$	$t * = {}^1/_2\, d_1 + 3^m = 8^m.4 = 2°06'$	
${}^1/_2\, d_1 + 3^m$	8.4	log sin $t *$	8.5640
$\alpha *$	$3^h25.8$	— cos $\delta *$	9.9894
1. $*$ observ., sidereal time.	3 17.4	— cosec $z *$	0.0458
$\div du$	$\div 1$ 19.6	log sin $\alpha *$	8.5992
1. $*$ observ., 57203.....	$1^h57^m.8$	$\alpha * = \alpha$ ☾ $= \mp$	$2°16'.7$
d_1	$+10.8$	*M. P.*	31 45.6
1. ☾ observ., 57203.....	$2^h08^m.6$	Horizontal readings	$29°28'.9$ / $34°02'.3$

In set II the observation of the star follows $2\ ({}^1/_2\, d_1 + 3^m) = 16^m.8$ upon the observation in set I viz. by clock time $2^h14^m.6$. In the case of the moon there may often be occasion to compute the moment

of observation in set II making allowance for the alteration of the right ascension, thus in the example quoted

$$2^h08^m.3 + 16^m.8 + \frac{129^s}{60} \times \frac{1}{60} \times 16.8 = 2^h25^m.7.$$

The observation journal.
Azimuth of the moon 25/IX 1907.

Observer: Wegener. Assistant: Koch.

	Horizontal circle	57203	z
f Tauri Mag. 4.3	29°28′.9	$1^h57^m.8$	64°.2
1. ☾ observation		2 08.3	62°.6
f Tauri	34°02′.3	2 14.6	
2. ☾ observation		2 25.7	

Telesc.	57203	Level W	Level E	Level computation	Telesc.	57203	Level W	Level E	Level computation
E	*f Tauri*	*13.4* / *3.8*	*1.8* / *15.4*	÷ 1.00	W	*f Tauri*	*1.0* / *14.7*	*12.5* / *3.0*	+ 1.05
	1 57 24.2	1 57 55.45				*2 14 16.9*	2 14 48.39		
	39.8	55.52				*32.0*	47.98		
	55.5	55.50				*44.7*	48.56		
	59.5	55.64				*48.2*	48.20		
	58 11.9	55.92				*15 04.3*	48.58		
	27.3	55.81				*19.7*	48.45		
	mean	$1^h57^m55^s.64$				mean	$2^h14^m48^s.36$		
	II ☾ limb	*4.7* / *12.9*	*16.3* / *1.4*	÷ 1.68		*II ☾ limb*	*16.7* / *2.7*	*5.0* / *14.1*	+ 1.23
	2 07 59.2	2 08 31.80				*2 25 16.0*	2 25 48.85		
	8 15.0	31.39				*32.0*	48.67		
	31.6	31.60				*45.0*	49.03		
	35.9	31.87				*48.7*	48.70		
	48.6	31.93				*26 05.3*	48.91		
	9 04.6	31.75				*21.5*	48.90		
	mean	$2^h08^m31^s.72$				mean	$2^h25^m48^s.84$		

Glimmer on the moon limb. Preliminary weight 1.

At the reduction to middle thread in the case of *f* Tauri no allowance is made for the fact that the observation falls outside the meridian. In the case of the moon a fictitious declination $[\partial\,☾]$ is computed in the following manner:

From the observations themselves it appears that the intervals between the outer threads are:

for telescope east $65^s.4$
„ „ west $65^s.5$
mean $65^s.45$.

From the table mentioned on p. 106 we get for $\delta = 0$ the interval between the outer threads $61^s.22$.

We now arrive at sec $[\delta \, \mathbb{C}] = \frac{65.45}{61.22}$, hence $[\delta \, \mathbb{C}] = 20°.7$.

With this value as an argument the values of the single thread intervals are interpolated in the above-mentioned table.

The preliminary weight given in the observation journal should only be regarded as an instantaneous, somewhat arbitrary estimate of the reliability of the observation. By the weight 1 is indicated a normally good observation.

The progress of the computation of the observation is given below, and it will be possible to follow it direct. Only the term $\frac{r}{a} \cdot \frac{\varphi \div \varphi'}{\omega}$ used in the computation of the parallax requires further explanation. In this term r is radius vector for the latitude φ.

a is the semi-major axis of the elliptical meridian of the earth.

φ' is the geocentric latitude and

ω is the radius expressed in seconds $= \frac{1}{\sin 1''}$.

For r expressed in metres there is (Bessel's values of the elements of the earth)

$\log r = 6.803918 + \{ 6.861585 \div 10 \} \cos 2\varphi \div \{ 4.2615 \div 10 \} \cos 4\varphi \ldots$

where $\{ \ \}$ indicates the logarithms of the co-efficients.

For a in metres there is $\log a = 6.804643$.

The difference between the geographical and the geocentric latitude is determined by $\varphi \div \varphi' = \{ 2.839257 \} \sin 2\varphi \div \{ 0.063059 \} \sin 4\varphi + \{ 7.4118 \div 10 \} \sin 6\varphi \ldots$

From these formulæ in the case of Danmarks Havn we arrive at the result:

$$\varphi \div \varphi' = 5'08''.6; \log \frac{r}{a} = 9.998623 \div 10 \text{ and}$$

$$\log \frac{r}{a} \cdot \frac{\varphi \div \varphi'}{\omega} = 7.17359 \div 10.$$

Furthermore used in the course of the computation:

Approximate value for the longitude $l_0 = + 1^h14^m50^s$

$\varphi = 76°46'16''$ [1])

1 division of the level $1p = 4''.45$.

[1]) The final computation of the latitude gave $\varphi = 76°46'14''.6 \pm 0''.4$. The fact that the value of φ used at the computation of the longitude is a little too great has no bearing on the result.

	The Moon				*f Tauri*	
	Telesc. east	Telesc. west			Telesc. east	Telesc. west
Clock time at the transit, U	$2^h08^m31^s.72$	$2^h25^m48^s.84$	U		$1^h57^m55^s.64$	$2^h14^m48^s.36$
Clock correction, du	$+1\ 19\ 41.54$	$+1\ 19\ 41.54$	du		$+1\ 19\ 41.54$	$+1\ 29\ 41.54$
Sidereal time, θ	$3\ 28\ 13.26$	$3\ 45\ 30.38$	θ		$3\ 17\ 37.18$	$3\ 34\ 29.90$
Approximate long., l_0	$+1\ 14\ 50$	$+1\ 14\ 50$	α		$3\ 25\ 46.41$	$3\ 25\ 46.41$
Sidereal time at Grw,	$4\ 43\ 03.26$	$5\ 00\ 20.38$	t		$\div\ 8^m09^s.23$	$+\ 8^m43^s.49$
Sidereal time at Grw. mean noon	$12\ 12\ 37.16$	$12\ 12\ 37.16$	t		$\div 2°02'\ 18''.4$	$+2°10'\ 52''.4$
Interval in sidereal time	$16\ 30\ 26.10$	$16\ 47\ 43.22$				
Converted to mean solar time	$16\ 27\ 43.84$	$16\ 44\ 58.13$				
	$= 16^h27^m.7307$	$= 16^h44^m.9688$				

From the Nautical Almanac is taken the variation in 1^m mean time for $\alpha\,\mathbb{C}$ and $\delta\,\mathbb{C}$ that is

at mean time	16^h	$\Delta\alpha\,\mathbb{C}$	$= 2^s.0803$	$\Delta\delta\,\mathbb{C}$	$= 8''.968$
—	17^h	—	$= 2.0810$	—	$= 8.888$, of which
—	$16^h\frac{27^m.7}{2}$	—	$= 2.0805$	—	$= 8.950$
—	$16^h\frac{45^m.0}{2}$	—	$= 2.0806$	—	$= 8.938$

From the Nautical Almanac as well as from Greenwich Observations 1907 [1]) we get

$\alpha\,\mathbb{C}$ at 16^h mean time	$3^h34^m16^s.05$	.....	$3^h34^m16^s.05$
Interpolation 2.0805×27.7307	$+\ 57.69$	2.0806×44.9688	$+\ 1\ 33.56$
Corr. after Greenw. Observations 1907	$+\ 0.25$	.....	$+\ 0.25$
$\alpha\,\mathbb{C}$ at the moment of observation	$3^h35^m13^s.99$		$3^h35^m49^s\ 84$
$\delta\,\mathbb{C}$ at 16^h mean time	$14°56'45''.0$	.....	$14°56'45''.0$
Interpolation 8.950×27.7307	$+\ 4\ 08.2$	8.938×44.9688	$+\ 6\ 41.9$
Corr. after Greenw. Observations 1907	$+\ 0.4$	.....	$+\ 0.4$
$\delta\,\mathbb{C}$ at the moment of observation	$15°00'53''.6$		$15°03'27''.3$

The moon's semi-diameter $s\,\mathbb{C}$ and horizontal parallax $\pi\,\mathbb{C}$.

As the Nautical Almanac only quotes these quantities for mean noon and mean midnight, it is necessary to compute them for the observation moments by interpolation with the second differences.

The following interpolation formulæ have been used:

$$f(a_n) = u_0 + \frac{n}{1}\Delta u_{+1/2} + \frac{n(n \div 1)}{1 \times 2} \cdot \frac{\Delta^2 u_{+1} + \Delta^2 u_0}{2}$$

The meaning of the individual quantities of the formula is:

Argument	Function	1st diff.	2d diff.
$a_{\div 1}$	$u_{\div 1}$		
		$\Delta u_{\div 1/2}$	
a_0	u_0		$\Delta^2 u_0$
		$\Delta u_{+1/2}$	
a_n			
a_{+1}	u_{+1}		$\Delta^2 u_{+1}$
		$\Delta u_{+3/2}$	
a_{+2}	u_{+2}		

[1]) Astronomical and Magnetical and Meteorological Observations made at the Royal Observatory, Greenwich, in the year 1907. Edinburgh 1909.

By way of example the computation of $s\,\mathbb{C}$ and $\pi\,\mathbb{C}$ is here carried out for the first observation moment.

By the argument a_0 is here understood the moment indicated in the table, which immediately precedes the moment of observation, midnight September 25 ɔ: Sept. 25.5 (astronomical date). The four arguments for which the values of the function ($s\,\mathbb{C}$, $\pi\,\mathbb{C}$) have to be taken from the table thus become a_{-1} = Sept. 25.0, a_0 = Sept. 25.5, a_{+1} = Sept. 26.0 and a_{+2} = Sept. 26.5. The moment a_n for which the function has bo be computed by interpolation becomes:

$$a_0 + \frac{4^h27^m.7307}{12} = \text{Sept. } 25.5 + 0.372, \text{ thus } n = 0.372.$$

By means of the data given in the Nautical Almanac the above-mentioned table is filled in as follows:

Argument	$s\,\mathbb{C}$	$\Delta s\,\mathbb{C}$	$\Delta^2 s\,\mathbb{C}$	$\pi\,\mathbb{C}$	$\Delta \pi\,\mathbb{C}$	$\Delta^2 \pi\,\mathbb{C}$
Sept. 25.0	15′21″.76			56′17″.11		
		÷ 5″.78			÷ 21″.20	
25.5	15.98		+ 0″.36	55 55.91		+ 1″.32
		÷ 5.42			÷ 19.88	
26.0	10.56		+ 0.45	36.03		+ 1.69
		÷ 4.97			÷ 18.19	
26.5	05.59			17.84		

From $f(a_n) = u_0 + \frac{n}{1}\,\Delta u_{+1/2} + \frac{n\,(n \div 1)}{1 \times 2} \cdot \frac{\Delta^2 u_{+1} + \Delta^2 u_0}{2}$ we now get for $n = 0.372$

$$s\,\mathbb{C} = 15'15''.98 \div 0.372 \times 5''.42 \div {}^1/_4 \times 0.372 \times 0.628 \times 0''.81$$
$$= 15'13''.92,$$
$$\pi\,\mathbb{C} = 55'55''.91 \div 0.372 \times 19''.88 \div {}^1/_4 \times 0.372 \times 0.628 \times 3''.01$$
$$= 55'48''.34.$$

For the second observation moment in a perfectly parallel manner is computed $n = 0.396$ which in its turn gives

$$s\,\mathbb{C} = 15'13''.78 \text{ and}$$
$$\pi\,\mathbb{C} = 55'47''.86.$$

The manner of computation of the difference $A\,\mathbb{C} \div A*$ indicating the formulæ used will appear from the table below.

If the approximated longitude, l_0, and the other elements of the computation had been correct, we should have found

$$A\,\mathbb{C} \div A* = 0.$$

This, however, has not proved to be the case, and we may now take it for granted that the reason for this is exclusively to be found

September 25th 1907		Telescope east		Telescope west	
Formulæ	Star and level.	*f Tauri* ÷ 1.00	☾II ÷ 1.68	*f Tauri* + 1.05	☾II + 1.23
Sidereal time, θ		3h17m37s.18	3h28m13s.26	3h34m29s.90	3h45m30s.38
Right ascension, α		3 25 46.41	3 35 13.99	3 25 46.41	3 35 49.86
Hour angle, $t = \theta \div \alpha$		÷ 8 09.23	÷ 7m00s.73	+ 8m43s.49	+ 9m40s.52
— , converted into degrees		÷ 2°02′ 18″.4	÷ 1°45′ 10″.6	+ 2°10′ 52″.4	+ 2°25′ 07″.8
Declination, δ		12°37′ 14″.2	15°00′ 53″.6	12°37′ 14″.2	15°03′ 27″.3
Azimuth of star and moon's centre.	log numerator	9.841487 *n*	9.697536 *n*	9.870874	9.836024
	log sin *t*	8.551085 *n*	8.485575 *n*	8.580472	8.625354
	— sec φ	0.640465	0.640465	0.640465	0.640465
	— cot δ	0.649937	0.571496	0.649937	0.570205
	— tan φ	0.628785	0 628784	0.628784	0.628784
	— cos *t*	9.999725	9.999797	9.999685	9.999613
$\tan A = \div \frac{\cot\delta \sec\varphi \sin t}{1 \div \cot\delta \tan\varphi \cos t}$	— cot δ tan φ cos *t*	1.278446	1.200077	1.278406	1.198602
	cot δ tan φ cos *t*	18.9866	15.8517	18.9848	15.7980
	1 ÷ cot δ tan φ cos *t*	÷ 17.9866	÷ 14.8517	÷ 17.9848	÷ 14.7980
	log(1 ÷ cot δ tan φ cos *t*)	1.254949 *n*	1.171776 *n*	1.254905 *n*	1.170203 *n*
	log tan *A*	8.586538 *n*	8.525760 *n*	8.615969	8.665821
	A	÷ 2°12′37″.0	÷ 1°55′18″.7	+ 2°21′54″.3	+ 2°39′08″.5
Parallactic angle, *p*, and true zenith distance, *z*.	log cot φ	9.371216	9.371216	9.371216	9.371216
	— cos *t*	9.999725	9.999797	9.999685	9.999613
	— tan *N*	9.370941	9.371013	9.370901	9.370829
	N	13°13′15″	13°13′21″	13°13′10″	13°13′03″
$\tan N = \cot\varphi \cos t$	$\delta + N$	25°50′29″	28°14′15″	25°50′24″	28°16′30″
	log tan *t*	8.55136 *n*	8.48578 *n*	8.58078	8.62574
	— sin *N*	9.35928	9.35933	9 35923	9.35917
	— sec ($\delta + N$)	0.04570	0.05503	0.04571	0.05512
$\tan p = \frac{\tan t \sin N}{\cos(\delta + N)}$	— tan *p*	7.95634 *n*	7.90014 *n*	7.98572	8.04003
	p	÷ 0°31′05″	÷ 0°27′19″	0°33′16″	0°37′42″
	log cot ($\delta + N$)	0.31487	0.27000	0.31490	0.26931
$\tan z = \frac{\cot(\delta+N)}{\cos p}$	— sec *p*	2	1	2	3
	— tan *z*	0.31489	0.27001	0.31492	0.26934
	z	64°09′34″	61°45′48″	64°09′39″	61°43′36″
Semidiameter, s ☾.	log s ☾		2.96091		2.96084
	— sin z ☾		9.94498		9.94483
Correction $= \pm \frac{s\,☾}{\sin z\,☾}$ (1st, 2d) limb	— correction		3.01593		3.01601
	Correction		÷ 17′17″.4		÷ 17′17″.5
Parallax.	log $\frac{r}{a} \cdot \frac{\varphi \div \varphi'}{\omega}$		7.1736		7.1736
	— π ☾		3.5248		3.5248
	— sin *A* * [1]		8.5862 *n*		8.6156
Correction $= \frac{r}{a} \cdot \frac{\varphi \div \varphi'}{\omega} \cdot \pi\,☾ \frac{\sin A *}{\sin z\,☾}$ [1]	— cosec z ☾		0.0550		0.0551
	— correction		9.3396 *n*		9.3691
	Correction		÷ 0″.2		+ 0″.2
Apparent zenith distances, z_a	log π ☾ sin z ☾		3.4698		3.4697
z_a ☾ = z ☾ + π ☾ sin z ☾ ÷ refraction	π ☾ sin z ☾		49′12″		49′12″
Barom. = 762 mm, Temp. = ÷ 10° C	Refraction	2′06″	2′00″	2′06″	2′00″
	z_a	64°07′28″	62°33′00″	64°07′33″	62°30′48″
Collimation and inclination.	log p [2]	0.6484	0.6484	0.6484	0.6484
	log c — i	1.4433 *n* 0.0000 *n*	1.4433 *n* 0.2253 *n*	1.4433 0.0212	1.4433 0.0899
Tel. east / Tel. west $\pm \frac{c}{\sin z_a}$, $c = \div 27''.75$; $\frac{i''}{\tan z_a}$	— cosec z_a — cot z_a	0.0459 9.6857	0.0519 9.7156	0.0459 9.6857	0.0521 9.7162
	— correction	1.4892 *n* 0.3341 *n*	1.4952 *n* 0.5893 *n*	1.4892 0.3553	1.4954 0.4545
	Correction	÷ 30″.8 ÷ 2″.2	÷ 31″.3 ÷ 3″.9	+ 30″.8 + 2″.3	+ 31″.3 + 2″.8
Summary of the results.	*A*	÷ 2°12′37″.0	÷ 1°55′18″.7	+ 2°21′54″.3	+ 2°39′03″.5
	Correction for semidiam.		÷ 17 17.4		÷ 17 17.5
	— - parallax		÷ 0.2		+ 0.2
	— - collim.	÷ 30.8	÷ 31.3	+ 30.8	+ 31.3
	— - inclin.	÷ 2.2	÷ 3.9	+ 2.3	+ 2.8
	A (corrected)	÷ 2°13′10″.0	÷ 2°13′11″.5	+ 2°22′27″.4	+ 2°22′25″.3
	A ☾ ÷ *A* *	÷ 1″.5		÷ 2″.1	

[1] In this term is employed the computed azimuth of the star for the apparent azimuth of the moon's limb, since by the nature of the observation they are very nearly equal.

[2] 1 p = the angular value of one division of the level = 4″.45.

in the error Δl_0 of the approximated longitude. In this manner we arrive at the following terms for the determination of Δl_0 [1])

$$\Delta l_0 = \frac{A\mathbb{C} \div A*}{f}, \text{ where}$$

$$f = \{ 9.39675 \} \Delta\alpha\mathbb{C} \frac{\cos\delta\mathbb{C} \cos p\mathbb{C}}{\sin z\mathbb{C}} \div \{ 8.22066 \} \Delta\delta\mathbb{C} \frac{\sin p\mathbb{C}}{\sin z\mathbb{C}}$$

The logarithms of the co-efficients indicated within { } hold good anywhere troughout the globe. For $\Delta\alpha\mathbb{C}$ and $\Delta\delta\mathbb{C}$ the values of the observation moments are to be used:

The computation of Δl_0 gives in the case in question:

Telescope east $\Delta l_0 = \div 2^s.7$; telescope west: $\Delta l_0 = \div 3^s.7$

mean value $\Delta l_0 = \div 3^s.2$, thus

$$l = l_0 + \Delta l_0 = 1^h14^m50^s \div 3^s.2 = 1^h14^m46^s.8.$$

The trifling discrepancy between "telescope east" and "telescope west" in the above example is accidental; generally it becomes considerably greater, which is only to be expected under the unfavourable conditions of observation.

There is consequently, as a rule, no occasion to work out the computation as circumstantially as in the example quoted. By looking upon the correction of the azimuths it will appear that one might very often dispense with the computation of parallax and collimation, as these quantities partly cancel each other when arriving at the mean of "telescope east" and "telescope west". The justification of this manner of proceeding is, however, dependent upon the position of the observations in relation to the meridian and on the general accuracy of the observation. As regards most of the results quoted below the computation has been carried out in the abbreviated manner.

We have already mentioned that it is possible to use two stars in connection with the moon, in which manner the accuracy of the observation may be somewhat increased. On the Danmark-Ekspedition this was only tried in a single case, but, on the other hand, according as we gained greater accuracy and routine, we several times observed two or three transits of moon and star on both sides of the meridian; this was e. g. the case as regards the five last-mentioned of the determinations of longitude given below. In the observation journal greater weight has been assigned to these five determinations than to the other ones. The results, however,

[1]) William Chauvenet: A Manual of Spherical and Practical Astronomy, 5th edition, Philadelphia and London, vol. 1 pp. 375—376.

do not seem to have become any surer by means of the more circumstantial method of observation, which is perhaps due to the circumstance that the rate of the watch at the low temperature becomes less reliable, the longer the observation lasts. Consequently when undertaking the final computation I have assigned the weight 1 to all of the twelve observations indicated below. The approximated value of the longitude has in each single case been $l_0 = 1^h14^m50^s$.

In the table I have under "Number of transits" given the number of moon transits on either side of the meridian. The temperature is quoted in order to give an idea of the conditions under which the observations were made.

Date 1907	Temp.	Number of transits	Δl_0 +	Δl_0 −	v	v^2	
Sept. 24	− 4° C.	1	..	4.1	− 4.4	19.36	
— 25	− 8	1	..	3.2	− 3.5	12.25	
— 29	−12	1	8.6	..	+ 8.3	68.89	
Oct. 22	−14	1	12.5	..	+12.2	148.84	
— 28	−14	1	5.3	..	+ 5.0	25.00	
— 29	−17	1	1.2	..	+ 0.9	0.81	Two stars
Nov. 17	−21	1	..	11.7	−12.0	144.00	
— 22	−24	3	12.0	..	+11.7	136.89	Lower culm.
— 22	−22	2	3.3	..	+ 3.0	9.00	
— 23	−27	2	..	10.4	−10.7	114.49	
— 24	−24	2	..	0.5	− 0.8	0.64	
— 25	−29	2	..	9.8	−10.1	102.01	
			42.9	39.7		782.18	

$$\text{Mean } \frac{42^s.9 - 39^s.7}{12} = + 0^s.3.$$

$$\text{Mean error of a single observation: } m = \sqrt{\frac{782.18}{11}} = 8^s.4$$

$$\text{Mean error of the mean: } \mu = \frac{m}{\sqrt{12}} = 2^s.4$$

Final result: $l = 1^h14^m50^s.3 \pm 2^s.4$ **w. of Grw.**

It may reasonably be assumed that the twelve determinations used give a fairly reliable value of the mean error of the mean, $\mu = 2^s.4$. This error of the mean may be considered an expression of the accuracy which may be obtained by determination of longitude by means of the moon azimuth under the particular conditions. It must be borne in mind that the mean error when expressed in time or arc must necessarily increase, according as we approach the

Poles. The extension east-west corresponding to $\mu = 2^s.4$ is at the latitude of Danmarks Havn ($\cos \varphi = 0{,}23$)

$$\mu = 256 \text{ metres}$$

which perhaps gives a better idea of the accuracy arrived at.

The uncertainty is, as will appear, rather great. Even if the accuracy is sufficient for all practical purposes, it would, however, be desirable to carry it considerably farther, in view of its importance to scientific research. It is to be supposed that something is to be gained by using a portable transit instrument (moon culminations), but fully satisfactory results will hardly be arrived at in Greenland, till telegraphic communication (wireless) has been established.

Determination of Latitude.

The method which is most suitable for a more accurate determination of latitude under high arctic conditions is, as far as I know, the measurement of the zenith distance in the meridian shown by Colonel von Sterneck.

A nearly equal number of stars south and north of the zenith are observed, and in such a manner that the sum of the zenith distances measured on either side becomes nearly alike. Every star is observed only once during the same night, that is in the meridian, which must thus be fairly well known. In this manner the zenith distance of every single star is only to the obtained under the presumption that the zenith point of the circle is known. This is, to be sure, never the case with sufficient accuracy, but it is of no importance, as one arranges things in such a manner that the error of the zenith point is eliminated when determining the final results. In case a star is observed, for instance with "telescope west", and if the latitude φ_w is computed on the strength of this, irrespective of the unknown reading x for the zenith point, then the real latitude will, apart from errors of observation, be $\varphi_w \pm x$. If then another star is observed with "telescope east", the latter gives in the same manner the latitude $\varphi_e \mp x$, so that the mean gives the latitude independent of the zenith point, provided the latter was constant.

The manner of proceeding is to observe a nearly equal number of stars in both instrument positions, at first irrespective of the fact whether the stars culminate towards the north or towards the south. The justification of this is that the zenith distance enters into the latitude with opposite signs for southern and northern stars ($\varphi = z_s + \delta_s$ and $\varphi = \delta_n - z_n$ or $\varphi = 180 - (\delta_n + z_n)$). If only two stars are used, a southern and a northern one, and if the reversal

of the instrument is left out, the error of the zenith point with its full value will enter into the latitude as shown on Fig. 6, in which manner the following result is arrived at

$$z_s = z^s - x \text{ and } z_n = z^n + x$$

It is a matter of course that besides the microscopes of the vertical circle the level of same must be read off with every observation, in order that all the readings of the circle may be reduced to the same reading of the level i. e. to the same zenith point.

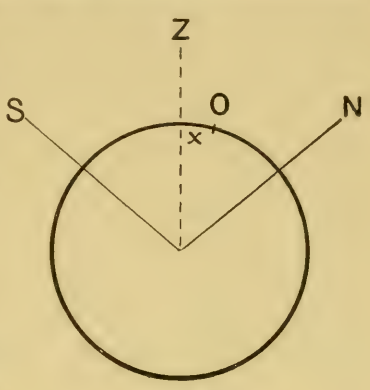


Fig. 6.

In view of the computation of the refraction the pressure of the air as well as the temperature have to be observed.

Stars, the zenith distance of which exceeds 50°, ought not to be used.

Under favourable conditions one may in the course of a single night make as many as fifty observations, and with a good instrument the latitude may in this manner be determined with a mean error of about 0″.2. The high arctic conditions are, however, not favourable; one becomes comparatively quickly indisposed, and it pays, therefore, to extend the observation over several occasions.

Especially in the course of the determinations of latitude, it was principally felt as a very serious drawback that we had not at our disposal a larger star catalogue than the Nautical Almanac. As early as the month of November the temperature became so low that conditions were unfavourable in cases where the utmost accuracy was aimed at. We had to profit by the moonlight nights during the months of September and October 1907 for the purpose of making determinations of longitude; several nights offered no prospect, owing to a cloudy sky or bad weather, and consequently we had only a few nights left for the determination of latitude and the investigation of the astronomical refraction (see pp. 136—147).

The preparations to be made for the observation are exceedingly simple. They consist in determining the meridian point of the horizontal circle, in selecting suitable stars from the catalogue and in making a list of the approximate clock times and of the zenith distances corresponding to the culmination. The observations 8/IX 1907 are given below. Each microscope is read off on both

graduations[1]). In this manner it might just have become possible to compute a micrometer correction. This, however, did not take place; I have simply taken the mean of the 2 (4) readings. 1 division of the level 4″.70. The barometer was read off in the "Villa"; the temperature given in parenthesis is that of the barometer.

Under the column "Star; clock time" the clock time of the culmination has been given, in preparation of the observation, while the moment of observation is recorded in the course of the observation itself. The idea was to insure against the observation falling too far outside the meridian, which was to be feared, as we did not use a meridian mark. We might possibly make a reduction to the meridian by means of the hour angle observed.

The level corrections are, as will appear, not added to the zenith distance but to the reading of the vertical circle.

From the observation table it will appear that stars have been observed, the zenith distance of which far exceeds 50°. The reason of this is that the aim of the measurements was a twofold one; partly to determine the latitude and partly to investigate the astronomical refraction.

Measurement of zenith distances 8/IX 1907.

Observer: Koch; Assistant: Wegener.

57203	*b*	*t*
21h07m	*754.8 (+ 16.3)*	*÷ 4.9*
22 05	*754.5 (+ 16.0)*	*÷ 5.6*
0 35	*753.7 (+ 13.5)*	*÷ 6.2*

Star; clock time	Culmination	Telesc.	*z*	Microscope I	Microscope II	$\frac{I+II}{2}$, *i*	Level Obs.	Level Obj.
η Pegasi, 3.1	S	W	47°.2	*312°52′08″*	*51′ 59″*			
21h20m27s					*50 56*	312°51′48″.0	*4.8*	*20.3*
20 14				*10*	*52 00*	+ 0.2	+ 0.05	
					50 53			
				312 52 09.0	51 27.0			

[1]) The double readings of microscope II are due to the fact that, in moist weather, the one of the parallel threads of the microscope was bent. In this case we only used the undamaged thread, making it coincide first with the one and then with the other side of the graduation in question.

A careful test proved that the mean of the corresponding two readings had the same accuracy as the reading of an ordinary coincidence, made by making the graduation bisect the space between two undamaged parallel threads.

Star; clock time	Culmination	Telesc.	z	Microscope I	Microscope II	$\frac{I+II}{2}$, i	Level Obs.	Level Obj.
β Urs. maj., 2.4	N	W	46°.4	*46° 13′ 21″*	*12′ 45″*			
21h37m59s					*11 41*	46°12′45″.5	*18.1*	*2.3*
37 13				*20*	*12 42*	÷ 10.8	÷ 2.30	
					11 34			
				46 13 20.5	12 10.5			
α Pegasi, 2.6	S	E	62.0	*61 55 10*	*54 40*			
21 41 56					*53 38*	61 54 37.5	*19.9*	*4.0*
41 55				*04*	*54 40*	÷ 2.6	÷ 0.55	
					53 34			
				61 55 07.0	54 08.0			
ψ Urs. maj., 3.2	N	E	58.2	*301 40 55*	*40 50*			
21 46 12					*39 41*	301 40 35.6	*7.0*	*22.7*
45 57				*54*	*40 51*	+ 11.0	+ 2.35	
					39 45			
				301 40 54.5	40 16.7			
β Cassiop., 2.4	S	E	18.2	*18 00 51*	*00 13*			
22 46 02					*59 12*	18 00 16.9	*20.1*	*4.2*
46 15				*49*	*00 17*	÷ 1.6	÷ 0.35	
					59 13			
				18 00 50.0	59 43.8			
B. A. C. 4165, 6.3	N	E	15.0	*344 52 34*	*52 03*			
22 55 27					*50 57*	344 52 02.9	*5.5*	*21.3*
55 40				*35*	*52 03*	+ 4.2	+ 0.90	
					51 02			
				344 52 34.5	51 31.3			
ε Androm., 4.6	S	E	48.0	*47 49 51*	*49 20*			
23 15 27					*48 23*	47 49 20.1	*19.0*	*3.2*
15 49				*51*	*49 18*	÷ 6.6	÷ 1.40	
					48 16			
				47 49 51.0	48 49.2			
∂ Piscium, 4.6	S	W	69.6	*290 14 24*	*14 18*			
23 25 42					*13 21*	290 14 07.9	*5.5*	*21.3*
25 54				*27*	*14 17*	+ 4.2	+ 0.90	
					13 25			
				290 14 25.5	13 50.3			
31 Comæ, 5.1	N	W	75.2	not observed				
23 29 00								
α Can. ven., 2.8	N	W	64.4	*64 15 37*	*15 07*			
23 33 26					*14 10*	64 15 09.3	*19.0*	*3.0*
33 11				*41*	*15 09*	÷ 7.1	÷ 1.50	
					14 12			
				64 15 39.0	14 39.5			
72 Piscium, 5.6	S	E	62.3	*62 10 38*	*10 08*			
23 41 58					*9 04*	62 10 07.0	*20.0*	*4.0*
41 58				*36*	*10 06*	÷ 2.4	÷ 0.50	
					9 10			
				62 10 37.0	9 37.0			

When computing the latitude it turned out that the observation journal contained eighteen stars with zenith distances below 52°. The latter were equally distributed over "telescope east" and "telescope west", while eleven culminated towards the south and seven towards the north. Even if the latter distribution is not so good as might be wished, I chose, however, to leave off here rather than to resort to stars with greater zenith distances.

The observations took place within two periods, viz. the early half of September and the early half of October. However, towards the end of September the correction of the zenith point was changed. In order to be able to compare the observations, I have for each period computed the zenith point correction and applied it to the latitudes computed, as shown in the table below.

Determinations of latitude 1907.
The Observatory at Danmarks Havn.

Star	Telescope	Culmin.	Zenith distance	Refraction	Reduc. to the meridian	Declination	Latitude W	Latitude E
8. Sept.							76°	
η Pegasi	W	S	47°08′11″.8	1′05″.3	0″.0	29°44′19″.8	53′36″.9	
β Urs. maj. .	W	N	46 12 34.7	1 03.8	+ 0.2	56 52 48.1	33.2	
β Cassiopeiæ	E	S	18 00 15.3	20.0	0.0	58 38 19.3		54.6
B. A. C. 4165.	E	N	15 07 52.9	16.4	0.0	88 12 54.9		55.8
ε Andom....	E	S	47 49 13.5	1 07.6	0.0	28 48 34.8		55.9
9. Sept.								
θ Urs. maj. .	W	N	50 59 16.0	1 14.7	+ 0.2	52 05 56.8	32.3	
16 Pegasi ...	W	S	51 22 50.4	1 15.0	÷ 0.3	25 29 31.9	37.0	
β Cassiop. ..	W	S	18 14 56.2	19.7	÷ 0.2	58 38 19.6	35.3	
B. A. C. 4165.	W	N	14 53 18.9	16.2	+ 0.1	88 12 54.5	30.3	
13. Sept.								
16 Pegasi ...	E	S	51 08 10.1	1 16.6	0.0	25 29 32.6		59.3
β Cassiop. ..	E	S	18 00 12.1	20.3	0.0	58 38 21.0		53.4
B. A. C. 4165.	E	N	15 07 56.0	16.7	0.0	88 12 53.3		54.0
						mean..	53′34″.17	38′55″.50
7. Oct.								
δ Draconis..	E	S	9 08 39.6	10.2	÷ 1.2	67 30 18.0		39 06.6
θ Urs. maj. .	W	N	50 59 31.9	1 17.2	0.0	52 05 50.2	53 20.7	
16 Pegasi ...	W	S	51 22 34.5	1 17.7	÷ 0.2	25 29 36.1	28.1	
13. Oct.								
δ Draconis..	W	S	9 23 05.6	10.2	÷ 6.7	67 30 18.1	27.2	
γ Cygni	E	S	36 40 22.9	46.4	0.0	39 57 55.8		05.3
o Urs. maj. .	E	N	42 18 32.0	56.5	0.0	61 01 27.5		04.4
						mean..	53′25″.3	39′05″.3

To be used in the computation of the refraction it was necessary on the "read" zenith distances to place a roughly computed zenith correction.

The reduction to the meridian is here, where the hour angles are quite small, computed from the simple formulæ

$$R_1 = \frac{15^2 \times 60^2}{2} \times \sin 1'' \times \frac{\cos\varphi \cos\delta}{\sin(\varphi \div \delta)} t^2 \text{ (upper culmination) and}$$

$$R_2 = \frac{15^2 \times 60^2}{2} \times \sin 1'' \times \frac{\cos\varphi \cos\delta}{\sin(\varphi + \delta)} t^2 \text{ (lower culmination).}$$

The hour angle is in these formulæ to be expressed in minutes.

From the means arrived at the corrections of the zenith points are computed

for Sept. 8, 9 and 13: $\Delta z_1 = 7'19''.3$,
for Oct. 7 and 13: $\Delta z_2 = 7'10''.0$.

If these corrections are applied, the latitude becomes:

		Culm. N	Culm. S
8. Sept.	η Pegasi	76°46′	76°46′17″.6
	β Urs. maj.	13″.9	
	β Cassiop.		13.9
	B. A. C. 4165	15.1	
	ε Androm.		15.2
9. Sept.	θ Urs. maj.	13.0	
	16 Pegasi		17.7
	β Cassiop.		16.0
	B. A. C. 4165	11.0	
13. Sept,	16 Pegasi		18.6
	β Cassiop.		12.7
	B. A. C. 4165	13.3	
7. Oct.	δ Draconis		16.6
	θ Urs. maj.	10.7	
	16 Pegasi		18.1
13. Oct.	δ Draconis		17.2
	γ Cygni		15.3
	o Urs. maj.	14.0	
		91.0	178.9

Result:

From the seven culminations towards north $\varphi_n = 76°46'13''.00 \pm 0''.6$
„ „ eleven „ „ south $\varphi_s = 76°46'16''.26 \pm 0''.5$

Taking the mean of the two values a possible systematic error in the refraction may be supposed to be eliminated, and one gets

$$\underline{\varphi = 76°46'14''.6 \pm 0''.4.}$$

The mean error of a single observation was 1″.7.

Astronomical Refraction.

In arctic literature one often comes across scattered remarks to the effect that the refraction in arctic regions is rather uncertain, although these assertions are as a rule not supported by observations taken for the purpose of directly substantiating the fact. The only expedition which has attempted scientifically to prove the distrust of the astronomical refraction is the Germaniaexpedition. The fact that two trained astronomers, Börgen and Copeland, who treated the matter on the basis of their own observations — observations which had, however, been undertaken with quite different ends in view — supplied a more solid foundation for the distrust and further carried it into a definite groove.

In „Die zweite deutsche Nordpolfahrt", Vol. II, pp. 707—709 Börgen and Copeland write:

„Wir haben nun noch Einiges über die bei der Reduction angewandte Refraction zu sagen. Bei der Berechnung der Beobachtungen auf Station Muschelberg ergaben die innerhalb 24 Stunden angestellten Zeitbestimmungen für das Chronometer Edward's einen so uregelmässigen Gang, dass sich derselbe nur schwer durch Beobachtungsfehler erklären liessen, zumal die beiden äusseren, auf derselben Seite des Meridians gemachten Zeitbestimmungen einen Gang ergaben, der nahe mit dem an Bord beobachteten übereinstimmte, indess schrieben wir die Unregelmässigkeit mehr den durch den rauhen Transport auf dem Schlitten und zuletzt in der Tasche hervorgebrachten Erschütterungen zu. Als wir jedoch die Polhöhenbestimmung reducirten, stellte sich zwischen den Beobachtungen der oberen und unteren Kulmination ein Unterschied heraus, der den w. F. des Mittels weit überschritt, namlich:

$$\varphi \begin{cases} O.\ C.^1) & 75°11'32''.90 \\ U.\ C.^1) & \quad\ 15''.98 \end{cases} \quad 16''.92$$

Als Ursachen dieses bedeutenden Unterschiedes bieten sich dar: 1) eine grosse Biegung des Fernrohrs, oder 2) eine kleinere Refraction, als sie von Bessel angegeben wird. Die erste Ursache schien von vornherein sehr unwahrscheinlich, da das Fernrohr sehr kurz und stark gebaut ist, auch zeigte ein directer in Leipzig angestellter Versuch, der allerdings nicht ganz befriedigend ausfiel, keine Biegung die irgendwie zur Erklärung dieser grossen Differenz ausreichen konnte; das Sinusglied der Biegung wurde nämlich durch Einstellung zweier Collimatoren gefunden $= +3''.4$.

Wir blieben daher bei der zweiten Erklärung stehen und fanden,

[1]) The zenith distances are about 52° and 82°; the probable error computed $\pm 0''.74$ and $\pm 1''.57$ respectively.

dass unter dieser Voraussetzung die Bessel'schen Refractionen mit 0.952 multiplicirt werden müssten. Leider wurde dies erst nach unserer Rückkehr nach Europa bemerkt, sonst hätten directe Versuche an Ort und Stelle über diesen interessanten und wichtigen Gegenstand Aufklärung geben müssen. Dies ist eine Aufgabe, welche jedenfalls zu den speciellen Untersuchungen einer spätern arctischen Expedition gehören muss.

Um indess nicht ohne Weiteres eine solche Hypothese anzunehmen, berechneten wir alle Beobachtungen, bei denen die Refraction eine Rolle spielte, sowohl mit den Bessel'schen als mit den verbesserten Refractionen, und da zeigte sich, dass alle Beobachtungen ohne Ausnahme durch Anwendung der kleineren Refraction eine wesentliche Verbesserung erfuhren. Um dies zu zeigen, mögen hier kurz die Resultate dieser doppelten Rechnung angeführt werden:

1) Zeitbestimmung auf Muschelberg.

Bessel'sche Refraction		Verbesserte Refraction
Juni 7.25	$\div 6^m 34^s.1$	$\div 6^m 35^s.9$
7.75	46.7	45.0
8.25	45.7	47.7

Wenn auch der Gang des Chronometers immer noch kein regelmässiger ist, so ist doch wenigstens kein Sprung nach rückwärts mehr vorhanden und es genügt die Annahme mässiger Beabachtungsfehler in Verbindung mit den Folgen des rauhen Transports in einer Lage, für die ein Boxchronometer gar nicht construirt ist, um die übrigbleibende Unregelmässigkeit zu erklären.

2) Azimut auf Sabine-Insel.

Das Azimut der geodätischen Station Nr. 5 wurde bestimmt, sowohl direct durch Beobachtung der Sonne in den Morgenstunden des 21. Juli, als auch durch Anschluss an den Cairn auf der Wallross-Insel, dessen Azimut in Verbindung mit Zeitbestimmungen am Nachmittage des 29., 30. Juni und 1. Juli festgestellt worden war.

Die Resultate sind:

Bessel'sche Refraction	Verbesserte Refraction
Direct ..... N. 4°5′12″.70	4°5′39″.5
Durch Wallross-Insel 4 6 6.2	40.1

3) Polhöhe von Sabine-Insel durch Zenithdistanzen der Sonne und von Polaris.

Die im Winter mittels Zenithdistanzen von Polaris und die durch Circummeridianzenithdistanzen gefundenen Polhöhen werden gleichfalls in weit bessere Uebereinstimmung gebracht, nämlich:

Bessel'sche Refraction	Verbesserte Refraction
Polaris[1]) 74°32′13″.72	74°32′15″.39
Sonne[2]) 20.20	16.78

Ferner ist zu bemerken, dass durch die Anwendung der mit der verkleinerten Refraction berechneten Zeitbestimmungen die vor und nach der Kulmination gemessenen Zenithdistanzen zur Bestimmung der Polhöhe in nähere Uebereinstimmung gebracht wurden.

Unter diesen Umständen haben wir uns zu der Annahme einer kleineren Refraction berechtigt gehalten."

Dr. R. Schumann, who worked out the observations made in West Greenland by E. v. Drygalski, writes regarding the refraction:[3])

„Zur ganzen bestätigen die Zeitbestimmungen v. Drygalski's das Bestehen von Abweichungen, deren Grund vorläufig allerdings mit grosser Wahrscheinlichkeit in einen anormalen Verhalten der Refraction zu suchen ist .... Jedenfalls bleibt die Natur dieser Abweichungen noch zu erkunden, und man muss .... unbedingt Börgen und Copeland beistimmen, wenn sie ..... sagen, dass spezielle Refraktionsuntersuchungen eine wichtige Aufgabe für spätere arktische Expeditionen bilden."

As will appear, Schumann also postpones the solution of the problem of arctic refraction to a future time. I will therefore call attention to the fact that the making of investigations of astronomical refraction which are so thorough as to — with any kind of justification — be called complete, is a task far too extensive to be undertaken by an expedition which does not make this part of the programme a factor to which all else is subservient. I will, however, add that the scientific result of such comprehensive research would hardly be reasonably proportionate to the time and strength required. As far as the Danmark-Ekspedition was concerned, exhaustive research was, at any rate, impossible, because a number of other and more urgent tasks fully took up the time of the scientific

[1]) Here there seems to be a printer's error; the greatest value of the Besslian refraction is 19″.1; the difference between the two methods of computation therefore cannot exceed 0″.9.

[2]) Observed in the days 28th June to July 1st 1870; the zenith distance about 51°. In the days August 5th—8th 1869 the latitude at circummeridian solar observations (upper culm.) with zenith distances of about 58° was determined at 74°32′5″.49 (verbesserte Refraction). Computed with the Besslian refraction this group of observations would give $\varphi = 74°32'10''$, in other words no mean agreement with the result of the corresponding computation of the Polaris observations.

[3]) Grönland-Expedition der Gesellschaft für Erdkunde zu Berlin 1891—1903 unter Leitung von Erich von Drygalski. Bd. II, p. 552.

staff and monopolised the instruments. However, as often as the opportunity offered, we busied ourselves with the matter.

From the following will appear what the Danmark-Ekspedition has done in the way of investigating astronomical refraction, and what may be deduced from these researches.

As a link in the investigations of the astronomical refraction we undertook a series of zenith distance observations of stars according to v. STERNECK's method (for particulars see pp. 130—135). In the course of the computation of the latitude of the Observatory we have already learnt that, in view of the refraction, it was necessary to distinguish between stars culminating to the north and south of the zenith. In a similar manner we find below the results of forty-nine observations of stars arranged according to the zenith distances (including the eighteen observations, which have already been used for the computation of the latitude). The reduction to the meridian and the declination are not given in the table. The temperature given under the pressure of the air is that of the barometer.

The forty-nine stars are arranged in two groups, in that those with a zenith distance exceeding 70° are collected in a group by themselves. This because we were taught by experience that when the zenith distance exceeded 70°, the uncertainty as regards the refraction became very great, as will also appear from a cursory glance at the latitudes computed on the strength of the latter group. Consequently one gets a more correct idea of the state of affairs when leaving out — for the present — these ten stars, so that the research only comprises zenith distances up to 70°.

The first mentioned group of thirty-nine stars is divided into two sub-divisions, of which the former consisting of eighteen stars with zenith distances up to about 51°15′ is the one on the strength of which the above-mentioned latitude was computed. A glance at the thirty-nine computed latitudes shows directly that the uncertainty is considerably greater in the last sub-division ($58° < z < 70°$). This appears more clearly when computing the latitude from the whole group, in the same manner as it was computed above from the eighteen stars. Result:

of 16 culminations towards north $\varphi_n = 76°46'13''.21 \pm 1''.0$
„ 23 „ „ south $\varphi_s = 76°46'16''.14 \pm 0''.6.$

If we strike the mean of these two values, whereby the error of the computed refraction may be supposed to be eliminated, we get

$$\varphi = 76°46'14''.68 \pm 0''.6.$$

The mean error of a single observation is about 3″.

As will appear, the value of the latitude coincides particularly well with the one already found — that this is partly chance is

Star	Telesc.	Temp.	Barometer	App. Zenitdisi.	Refraction	φ Culmination N	φ Culmination S
						76°46′	
δ Draconis	E	+ 9.0	761.6 (+ 15.5)	9°15′49″.7	10″.2		16″.6
δ Draconis	W	+ 14.2	748.1 (+ 15.5)	9 15 55.5	10.2		17.2
B. A. C. 4165	E	+ 5.8	754.1 (+ 14.0)	15 00 33.6	16.4	15″.1	
B. A. C. 4165	W	+ 3.0	753.1 (+ 15.9)	15 00 38.2	16.2	11.8	
B. A. C. 4165	E	+ 5.2	760.7 (+ 16.5)	15 00 36.7	16.7	13.3	
β Cassiopeiæ	E	+ 5.8	754.1 (+ 14.0)	18 07 34.7	20.0		13.9
β Cassiopeiæ	W	+ 2.1	753.1 (+ 15.9)	18 07 36.9	19.7		16.0
β Cassiopeiæ	E	+ 5.2	760.7 (+ 17.0)	18 07 31.4	20.3		12.7
γ Cygni	E	+ 13.8	748.0 (+ 16.0)	36 47 33.0	46.6		15.3
o Urs. maj.	E	+ 13.8	748.0 (+ 16.0)	42 11 21.9	56.5	14.0	
β Urs. maj.	W	+ 5.0	755.4 (+ 16.3)	46 19 54.0	1′ 03.8	13.9	
η Pegasi	W	+ 5.0	755.4 (+ 16.3)	47 00 52.5	1 05.3		17.6
ε Andom.	E	+ 5.8	754.1 (+ 14.0)	47 56 32.8	1 07.6		15.2
θ Urs. maj.	W	+ 3.0	753.5 (+ 17.1)	51 06 35.3	1 14.7	13.0	
θ Urs. maj.	W	+ 9.2	761.4 (+ 17.3)	51 06 42.0	1 17.2	10.7	
16 Pegasi	W	+ 2.8	753.5 (+ 17.1)	51 15 31.1	1 15.0		17.7
16 Pegasi	E	+ 5.8	760.3 (+ 17.3)	51 15 29.4	1 16.6		18.6
16 Pegasi	E	+ 9.6	760.8 (+ 16.3)	51 15 24.4	1 17.7		18.1
ψ Urs. maj.	E	+ 5.0	755.4 (+ 16.0)	58 11 54.1	1 38.0	17.9	
ψ Urs. maj.	E	+ 2.3	753.5 (+ 17.1)	58 11 56.6	1 36.8	16.8	
ψ Urs. maj.	W	+ 5.2	761.7 (+ 17.9)	58 11 57.3	1 38.9	15.1	
α Pegasi	E	+ 5.0	755.4 (+ 16.0)	62 01 54.2	1 54.4		21.1
α Pegasi	E	+ 2.5	753.5 (+ 17.1)	62 01 48.4	1 53.0		14.0
α Pegasi	W	+ 5.2	761.7 (+ 17.9)	62 01 50.3	1 55.4		18.9
72 Piscium	E	+ 5.8	754.1 (+ 14.0)	62 17 23.9	1 55.8		17.3
α Canum Venat.	W	+ 5.8	754.1 (+ 14 0)	64 22 21.5	2 06.7	12.7	
α Canum Venat.	E	+ 3.5	752.8 (+ 14.2)	64 22 31.8	2 05.4	03.8	
α Canum Venat.	W	+ 5.5	760.7 (+ 16.5)	64 22 19.9	2 07.6	14.4	
ε Pegasi	E	+ 2.8	753.5 (+ 17.1)	67 16 40.5	2 23.1		13.9
ε Pegasi	W	+ 5.8	760.3 (+ 17.3)	67 16 41.8	2 26.1		18.6
ε Pegasi	E	+ 9.6	760.8 (+ 16.3)	67 16 37.7	2 28.3		18.3
α Lyncis	E	+ 3.0	753.5 (+ 17.1)	68 24 16.9	2 31.4	06.9	
α Lyncis	W	+ 6.2	760.2 (+ 17.0)	68 24 01.3	2 34.6	20.0	
α Lyncis	E	+ 9.2	761.4 (+ 17.3)	68 24 01.5	2 36.6	11.9	
μ Aquilæ	E	+ 9.4	761.6 (+ 15.5)	69 32 29.5	2 46.3		18.4
μ Aquilæ	W	+ 14.2	748.1 (+ 16.0)	69 32 26.4	2 46.3		18.8
δ Piscium	W	+ 5.8	754.1 (+ 14.0)	69 38 28.6	2 43.3		10.1
δ Piscium	E	+ 3.0	753.1 (+ 15.9)	69 38 26.4	2 41.3		06.3
δ Piscium	W	+ 5.7	760.7 (+ 16.5)	69 38 33.3	2 44.6		16.7
				Sum total	43′1084″.6	211″.3	371″.3
				Mean of 39 (16 + 23) observations	94″.0	13″.21	16″.14

φ = 76° 46′ 14″.68

Star	Telesc.	Temp.	Barometer	App. Zenitdist.	Refraction	φ Culmination	
						N	S
						76°46′	
α Geminorum..	E	÷ 9.4	761.6 (+ 15.5)	71°05′23″.2	3′00″.8	08″.9	
α Geminorum..	W	÷ 14.2	748.1 (+ 16.0)	71 05 22.7	3 01.2	09.2	
δ Aquilæ	W	÷ 9.4	761.6 (+ 15.5)	73 46 47.6	3 32.1		17″.9
δ Aquilæ	E	÷ 14.2	748.1 (+ 16.0)	73 46 35.0	3 32.3		05.2
β Geminorum..	W	÷ 9.4	761.6 (+ 15.5)	74 55 07.8	3 48.6	06.5	
β Geminorum..	E	÷ 14.2	748.1 (+ 16.0)	74 55 07.8	3 48.7	06.5	
δ Leonis.....	W	÷ 2.3	753.5 (+ 17.1)	82 04 53.1	6 50.8	16.4	
δ Leonis.....	E	÷ 5.2	760.7 (+ 17.0)	82 04 45.4	6 59.9	15.6	
γ Leonis.....	W	÷ 2.5	753.5 (+ 17.1)	82 47 25.1	7 28.0	24.7	
ψ^3 Aquarii.....	W	÷ 2.1	753.1 (+ 15.9)	86 39 12.0	13 52		10.2

shown by the terms of accuracy — but the mean errors show at the same time that the result must rather be supposed to have lost in reliability by being computed from all the thirty-nine stars; in other words, the opposite of what one would be justified in expecting, unless one of the sources of the error — the uncertainty of the refraction — played a much greater part as regards the twenty-one last-mentioned stars than as regards the eighteen first-mentioned ones.

The difference between the two values of the latitude corresponding to the culmination north and south of the zenith shows that the values computed for the refraction have on an average been too great. Accordingly one was justified in expecting that this difference would increase proportionally to the refraction. However, this does not appear from the observations; the difference which arises between the culminations north and south of the zenith is practically speaking the same in the case of the eighteen stars with small zenith distances as in the case of the entire group of the thirty-nine stars. There is, however, nothing to be alarmed at in this state of affairs, which is principally due to the fact that the first sub-division with small zenith distances comprises far too few stars to enable one to get even a fairly reliable impression of the error of refraction, which is here bound to be very slight i. e. considerably smaller than the error arising from pointing the star. The idea least open to objection as regards the error of the computed refraction one forms by treating the entire group of thirty-nine stars together. The mean value of the refraction computed for all thirty-nine stars is 94″.0, whereas the difference between the two values of the latitude computed from southern and northern stars is 2″.93.

In case we suppose this difference to be exclusively due to the refraction, the error of same as computed becomes

$$\Delta r = \div {}^{1}/_{2} \cdot \frac{2.93}{94} r = \div \frac{1}{64} r$$

where r is the value indicated by Bessel.

It might thus seem as if the computed value of the refraction had been a good deal too great, and in so far the result of the investigation coincides with the view expressed by Börgen and Copeland; but here also the agreement ceases, as they estimated the error of the computed refraction at $\div \frac{1}{21} r$, or in other words, three times the value deduced above. It would be absurd to deduce a term of accuracy of this value. The fact that it does not appear directly from the latitudes computed that the values of the northern culmination decrease, while those of the southern increase with the zenith distances, already shows, in a sufficiently clear manner, the unreliability of the correction deduced. In appraising the uncertainty I shall only add that by including the ten last-mentioned stars with zenith distances from76° to 86½°, the result would have been:

$$\Delta r = \div \frac{1}{112} r$$

During the period from the end of July till the beginning of October 1907 we performed a series of circummeridian zenith distance observations of the sun. Each group of observations consisted of six with "telescope right" and six with "telescope left". Of these six sets of zenith distances three were measured to the lower limb, the other three to the upper limb.

In the tables below the results of these groups of observations are given; besides I have included the result of a single group, measured on June 3rd 1908.

In all we are dealing with $26 \times 12 = 312$ observations of the limb of the sun, of which 120 with zenith distances below 70°. Within each group the single observations harmonize very well. An investigation of the accuracy of the observations in the case of two groups gave the mean error of the single observation of a limb from 2″ to 4″ (28/VII and 24/VII).

The results are here, as in the case of the star observations, collected in two tables corresponding to the zenith distances below and over 70°.

It is apparent that the value of the latitude which may be deduced from the ten determinations, the zenith distances of which are below 70°, coincides pretty well with the corresponding value

of the star observations. The deviation is not so great but that it may find its natural explanation through the mean error. As we are here only dealing with observations of the sun near its upper culmination, it was to be expected, according to the above, that the refraction computed and so also the latitude would appear to be too great. There is perhaps a tendency in that direction, in that the value found is 0″.7 larger than that found by means of the star observations.

The mean value of the Besslian refraction corresponding to the ten first-named determinations of latitudes by means of the sun is

Determinations of latitude by means of circummeridian zenith distances of the sun.
The Observatory at Danmarks Havn.

Date	Aproximate Temp.	Aproximate Zenith-dist.	Latitude Culmination N	Latitude Culmination S
			76°46′	
6. June 08	÷ 2	55°		17″.2
23. July 07	+ 10	56		14.2
24. —	+ 6	57		16.6
26. —	+ 10	57		13.3
28. —	+ 9	58		17.3
29. —	+ 6	58		17.9
31. —	+ 11	58		14.7
23. August 07	+ 4	65		11.6
25. —	+ 1	66		16.6
29. —	+ 5	67		13.6
		Mean..	$\varphi = 76°46'15''.3 \pm 0''.7$	
8. Sept. 07	0	71		11.6
10. —	+ 3	72		10.6
12. —	+ 1	72		09.1
13. —	÷ 2	73		09.5
15. —	÷ 4	73		08.9
6. Oct. 07	÷ 10	82		05.6
7. —	÷ 4	82		14.8
12. —	÷ 10	84		03.5
23.—24. July 07	+ 2	83	16″.7	
24.—25. —	+ 1	83	18.9	
25.—26. —	+ 7	83	16.5	
27.—28. —	+ 6	84	17.2	
29.—30. —	+ 1	84	11.7	
30.—31. —	+ 7	85	22.6	
3.—4. Aug. 07	+ 3	86	16.2	
4.—5. —	+ 7	86	11.3	
		Mean..	15″.1	09″.2

104″. If applying the factor of reduction determined above $\div \frac{1}{64}$ the result would be $\varphi = 76°46'13''.7$ which shows that the factor of reduction is in this case too great. As the observations of the sun are carried out in temperatures which are 10°—15° higher than the corresponding temperatures in which the star observations have taken place, this might in itself also seem quite reasonable. The material is, however, too slight to admit of anything being based upon it in this respect.

If we consider the determinations of latitude at the great zenith distances from 71° to 86°, one must at once be struck by the fact that while the lower culminations give a fairly correct value of the latitude, the upper culminations give a value which is far too small; so in this case the refraction computed must have been too small.

It is reasonable to assume that there are local disturbances which make themselves felt in the atmosphere. All the observations of the upper culmination with large zenith distances fall within the period Sept. 8th to October 12th i. e. the period of the year when mirages over the fjord and the sea are everyday phenomena (as to this see chapt. VI), and the sights at the upper culmination happen to traverse the fjord, where the disturbances in the lower strata of air must be supposed to be greater.

The fact that the eight groups of observations at the lower culmination with zenith distances between 83° and 86° give such a good value of the latitude is due to fortuitous circumstances, as will easily appear from the desultory nature of the single values. There is, however, probably some connection between the fact that the error is rather evenly distributed on both sides of the real value, and the fact that these observations are made in the height of summer, when the atmosphere is not influenced in any considerable degree either by the melting of snow or the freezing of the water.

Through their determinations of time by means of the sun Börgen and Copeland found support for their supposition that the Besslian refraction was too great. It was, therefore, quite natural for us to direct our attention to this point. With the object of computing the correction of the mean time chronometer 57310, we made in September 1907 a series of zenith distance observations of the sun near the prime vertical; as a further test the clock correction was a few times determined by transits on the vertical af Polaris. Each group of zenith distance observations consisted of twelve, three sets of observations to the upper limb and three sets to the lower. Within the same group the observations to the same limb generally corresponded very well, whereas the results of the upper and lower

limb might differ by as much as six seconds of time; however, as a rule, the difference was only one or two seconds.

As will appear from the table below the determinations of time by means of the sun were carried out by zenith distances varying from 82° to 86°. The uncertainty caused by the refraction must here be supposed to be very great. As an error of 3″ in the zenith distance near the prime vertical, as far as Danmarks Havn is concerned, gives a clock error of about 1ˢ, the clock corrections computed from the observations of the sun must be rather unreliable. On the other hand it was only to be expected that a systematic error of the computation of the refraction would be comparatively more obvious in the case of the large zenith distances than otherwise.

Results of determinations of time in September 1907.

Astronomical date	Clock time 57310	Approximate zenith distance	Clock correction 57310	Rate for 24 hours
8. Sept.	5h.9	84°	+ 2m30s.1	
8. —	(10.1)	Polaris' vertical	(26.1)	
8. —	18.5	83	27.5	+ 0s.8
9. —	5.8	84	27.3	
9. —	(9.9)	Polaris' vertical	(26.9)	
9. —	18.5	83	27.4	
11. —	5.8	85	27.1	+ 0s.3
12. —	5.5	84	27.9	
12. —	(9.4)	Polaris' vertical	(27.8)	
12. —	19.1	82	25.5	
15. —	5.6	86	27.7	÷ 0s.4
15. —	18.7	84	24.8	
17. —	(8.6)	Polaris' vertical	(25.8)	
17. —	19.0	84	25.4	÷ 1s.4
18. —	5.5	86	24.3	
18. —	(14.0)	Polaris' vertical	(24.1)	
18. —	19.0	84	22.6	

The rate is deduced from the transits on the vertical of Polaris, which in this case may be considered faultless. It will appear that the clock rate, though even, has been rather variable.

The series of observations is very short. However, it shows with sufficient clearness that there is no pronounced systematic difference between the observations of the forenoon and those of the afternoon. The zenith distances being so great it is rather surprising that the clock corrections computed from the observations of the sun are not more uneven or subject to greater errors.

It should be remarked that the sights, both towards east and west, traverse the land.

The total impression gained from the researches of the Danmark-Ekspedition as regards the astronomical refraction may hardly be said to support the surmise put forth by Börgen and Copeland. The observations of stars, it is true, seem to indicate that the Besslian refraction was too great; but the deviation from the Besslian value is at any rate much smaller than supposed by Börgen and Copeland. As regards the observations of the sun we did not succeed in getting a fairly reliable indication of a definite tendency; these observations in reality only show the well-known general uncertainty which is inseparable from the great zenith distances. However, the eight determinations of latitude by the lower culmination of the sun and with zenith distances of from 83° to 86° give a very good value of the latitude, and in the same manner the twelve determinations of time by means of the sun — six towards east and six towards west — with zenith distances from 82° to 86° give upon the whole rather good results. In the case of the lower culmination as well as towards east and west the sights traverse the land.

On the other hand the eight determinations of the latitude by the sun at the upper culmination and with zenith distances between 71° and 84° show quite a definite tendency, which, in all probability, has a certain bearing upon the fact that the rays of the sun pass very flat through strata in the air in which mirages occur i. e. strata of the air the index of refraction of which varies greatly. Even though the single strata must in the main be supposed to extend horizontally, there are, purely locally, undoubtedly still considerable deviations from this, and in particular deviations from the horizontal extension of the boundary surfaces of the strata might be expected near the coast. But so the base of the theoretically computed refraction fails altogether.

If the surmise here set forth holds good, we must suppose that the astronomical refraction at great zenith distances is subject to purely local anomalies which change with the seasons. The observations of the Danmark-Ekspedition only contain a very faint indication of this (the difference between the latitude determined by means of observations of stars and the sun in the upper culmination and by zenith distances up to 70°). The observations in Germania Harbour where the observatory was situated on a small peninsula projecting from a comparatively mountainous coast point, in a higher degree, towards such a change according to the season, in that the determina-

tion of latitude, by means of the sun, in the upper culmination within the period

5th to 8th August (midsummer) . . . . . gave $\varphi = 74°32'10''$
28th June to 1st July (the snow melting period) „ $\varphi = 74°32'20''$.

Terrestrial Refraction.

The frequently occurring mirages, both directly on the sea and in the higher air strata over land, were suggestive of peculiar refraction conditions in the atmosphere. The sending up of kites and balloons showed that reckoning from a few metres above sea level there was as a general rule an increase of temperature (inversion) for the first two hundred metres, whereupon the temperature fell, so that at a height of 500 metres there was nearly the same temperature as at the place of ascension (about 5 metres above sea level). It was thus — for this reason only — to be expected that the terrestrial refraction at Danmarks Havn must be different, according as the lines of vision ran under about 200 metres or extended to higher altitudes.

Already by the computation made during the winter of 1906—7 of the triangulation net measured in the course of the autumn, it became evident that the co-efficient of refraction varied rather much (see the computation of the altitudes of the points of triangulation pp. 229—230), and this was the reason why after my return from the great sledge-trip in the spring of 1907 I made up my mind to carry on researches of the terrestrial refraction. These researches were intended to comprise the determination of the mean value of the co-efficient of refraction in the case of sights across the land as well as those across the sea.

In the case of the latter it would be sufficient from the permanent Observatory to level at one or more points of the sea horizon. The co-efficient of refraction might then be computed from the formula:

$$1 \div k = \left(\frac{z \div 90°}{\omega}\right)^2 \frac{R}{2\,h}$$

where z is the zenith distance of the sea horizon, R is the radius of curvature of the earth corresponding to the sight, while h is the altitude of the telescope, and k is the co-efficient of refraction.

In the case of sights across land it proved the best method to use reciprocal, simultaneous measurements of zenith distances. When measuring from A the zenith distance z_1 of the telescope in B, and measuring at the same time from B the zenith distance z_2 of the telescope in A one gets with approximation

$$k = 1 \div \frac{R}{\omega\, D}\,(z_1 + z_2 \div 180°)$$

where D means the distance between A and B.

Reciprocal, simultaneous zenith distances.

The Observatory — Cairn X.

The one of the two points must be the Observatory; as the second point we chose Cairn X, which lay at an altitude of 426 metres above sea level. This corresponded very well with the normal position of the inversion of temperature. The distance of Cairn X from the Observatory was $7^1/_2$ km.

With the view of enabling us to make exact observations from Cairn X to the Observatory there was in the neighbourhood of the latter set up an ordinary hour glass signal (see Fig. 7), the position of which in relation to the telescope of the Observatory vas determined by the following elements:

Fig. 7.

Horizontal distance from the centre of the Observatory to the cross of the signal 15.9 m.

Zenith distance of the cross from the Observatory 79°22′.

Angle X - Observatory-Cross 50°11′5.

In order to be able to point Cairn X sharply from the Observatory it was provided with a special sighting mark, in that a stanchion to which was attached a wooden disc was run through it (Fig. 8).

The expedition only having at its disposal one large universal instrument, one of the small instruments had to be used for the observations from Cairn X. The small instrument naturally could not furnish the same degree of accuracy as the larger one, which was besides firmly fitted into a granite pillar. In order to remedy this drawback a particularly solid tripod, which was firmly planted into the soil at Cairn X was made for the small instrument (see chapter VI, Fig. 88). Further the little instrument was, during the observations, shielded against the rays of the sun by means of an umbrella. Finally the observations at Cairn X were begun five minutes before the cor-

responding observations in the Observatory and continued for five minutes longer. With the permanent instrument in the Observatory observations, in each case, were made for about fifteen minutes, thus with the small instrument for about twenty-five minutes.

The position of the small instrument in relation to Cairn X was determined by the following elements:

Oblique distance from instrument to the centre of wooden disc 4.69 m.

Zenith distance of the centre of the wooden disc from the instrument 45°59′.

Angle X-Instrument-Cross (*K*) 164°41′.

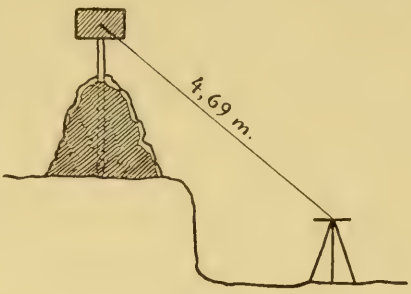


Fig. 8.

Fig. 9 shows, in a horizontal projection, the reciprocal position of the Observatory, Cross (*K*); Cairn X and the small universal instrument (*I*).

In the figure are given:

$O\,X = 7494.5$ m.
$O\,K = 15.19$ m.
$I\,X = 4.69 \sin 45°69' = 3.37$ m.
$< X - O - K = 50°11'.5$.
$< X - I - K = 164°41'$.

For $< I - O - X$ we get $< O = \omega \frac{3.37}{7494} \sin 164°41' =$ about 24″ = about 0′5.

Fig. 9.

$K\,E \perp O\,I$; $O\,E = O\,K \cos 50°12' = 9.72$ m; $K\,E = O\,K \sin 50°12' = 11.67$ m.

From $\triangle K\,I\,O$ we get $< I = \omega \frac{K\,E}{I\,E} =$ about $\omega \frac{11.67}{7494.5 \div 9.72 \div 3.37} = 5'22'' =$ about 5′.5.

From $\triangle O\,X\,I$ we get $< X = 180° \div (164°46'.5 + 0'5) = 15°13'$ from which in its turn, $I\,D$ being vertical on $X\,O$

$X\,D = 3.37 \cos 15°13' = 3.25$ m.
$I\,O = O\,X \div X\,D = 7491.2$ m.

In Fig. 10 the sights OX and IK (small instrument—Cross) have been revolved upon the vertical plane containing OI.

Fig. 10.

The sight from O to X is to be carried to point P, situated in the vertical XQ and on the line OI. In a corresponding manner the sight from I to K is to be carried to point E in the vertical KS.

Known beforehand: The zenith distance of X from O 86°50′15″; further

$$\left.\begin{aligned} XQ &= 4.69 \cos 45°59' = 3.26 \text{ m.} \\ IQ &= XD \text{ (Fig. 9)} = 3.25 \text{ m.} \\ OS &= OE \text{ (Fig. 9)} = 9.72 \text{ m.} \end{aligned}\right\} \text{(approximation)}$$

$$SK = 2.85 \text{ m.}$$

$$EK = 2.85 \div 9.72 \tan 3°09' = 2.31 \text{ m.}$$

$$PX = 3.26 \div 3.25 \tan 3°09' = 3.08 \text{ m.}$$

After this we get the corrections of the zenith distances measured from I to K.

$$\Delta z_K = +\omega \frac{2.31}{7491.2 \div 9.7} = +1'03''.7;$$

from O to X.

$$\Delta z_X = +\omega \frac{3.08}{7494.5} = +1'24''.8.$$

In the zenith distances given in the following between the Observatory and Cairn X these corrections are applied.

In order to be able to compute the co-efficient of refraction we must finally know the radius of curvature R.

We get $$\frac{1}{R} = \frac{1}{M} \cos^2 a + \frac{1}{N} \sin^2 a.$$

where M and N are the radii of curvature of the meridian and its normal segment, and where a is the azimuth of the segment in question. In the case of the ensuing computation it has, however, not been necessary to make allowance for the azimuth; it has been sufficient to put $R = \sqrt{MN}$ and from this to compute R for the latitude of the Observatory. By interpolating in the tables of $\log \frac{\omega}{M}$ and $\log \frac{\omega}{N}$ p. 235 we get

$$\log \frac{R}{\omega} = 1 : 49150.$$

As an example of the reciprocal measurements, I shall here give the first mentioned of the observations quoted below.

The Observatory, 11th August 1907
Observer and assistant: WEGENER
Begun *1h30*; finished *1h43*
$t = +8.0$; $b = 757$; degree of moisture *49 %*; wind *WNW 3* m; cover of clouds 2°, *a—cu*; 1 division of the level 5″.4.

Telescope left				Telescope right			
Microscope		Level		Microscope		Level	
I	II	Obs.	Obj.	I	II	Obs.	Obj.
86°44′44″	*44′40″*	*15.3*	*6.7*	*273°01′19″*	*01′38″*	*10.5*	*19.5*
48	*48*	*15.4*	*6.7*	*18*	*38*	*10.5*	*19.4*
49	*44*	*15.3*	*6.7*	*17*	*36*	*10.2*	*19.2*
45	*43*	*15.6*	*6.9*	*20*	*39*	*10.2*	*19.2*

$z = 86°51′28″.2$.

Cairn X, August 11th 1907
Observer and assistant: KOCH
Begun at *1h25*; finished at *1h50*
$t = +9.0$; wind *WNW 2* m; cover of clouds *1°*, *a—str.*; *haze, glimmer*; 1 division of the level = 22″.5.

Telescope left				Telescope right			
Vernier		Level		Vernier		Level	
A	B	Obs.	Obj.	A	B	Obs.	Obj.
266°50′.6	*51′.1*	*12.8*	*5.2*	*93°09′.3*	*09′.0*	*2.5*	*10.1*
50.6	*51.1*	*13.0*	*5.3*	*09.3*	*09.1*	*2.4*	*10.1*
50.7	*51.1*	*12.9*	*5.2*	*09.3*	*09.1*	*2.5*	*10.0*
50.6	*51.0*	*12.8*	*5.2*	*09.3*	*09.2*	*2.5*	*10.1*
50.5	*51.0*	*12.9*	*5.3*	*09.2*	*09.0*	*2.7*	*10.3*
50.6	*51.2*	*12.8*	*5.2*	*09.3*	*09.1*	*2.7*	*10.3*
50.6	*51.1*	*12.8*	*5.2*	*09.2*	*09.0*	*2.7*	*10.3*
50.7	*51.1*	*12.8*	*5.2*	*09.5*	*09.2*	*2.8*	*10.3*
50.6	*51.1*	*12.8*	*5.2*	*09.4*	*09.2*	*2.8*	*10.3*
50.6	*51.1*	*12.9*	*5.3*	*09.3*	*09.2*	*2.4*	*10.0*

$z = 93°09′40″.2$.

The mean error of the single observation with the instrument of the Observatory is a couple of seconds. From the example quoted of the series of observations made with the small instrument one gets the immediate impression that the observations are particularly good. However, we must not overlook the fact that here, where

everything is arranged in such a manner as to create the most favourable conditions possible for the observations (protection against wind and sun, a particularly solid foundation), the personal estimate of the observer as regards the reading on circle and level come to exercise a comparatively great influence. The accuracy attained is therefore probably smaller with the small instrument than would be indicated by a mean-error computation. Add to this, that an estimate of the reliability of the refraction co-efficient, based exclusively on a determination of the mean error of the zenith distances measured, would leave out of consideration the most important source of the error, that is the error of the presupposition, on which the formula $k = 1 \div \frac{R}{\omega D}(z_1 + z_2 \div 180°)$ is based. The hypothesis forming the basis of this formula is that the line of vision between the two telescopes in A and B may be considered as coinciding with the circular arc touching the two sights AB and BA in the reticule of the telescopes. This presupposes the refraction to be the same in all points of the line of vision. However, as a general rule, this is only the case with a more or less rough approximation, and in the following we will see that cases must often occur where the refraction is widely different in the various parts of the line of vision. We have, however, no better hypothesis to go upon in computing the co-efficient of refraction, k, and so we must be content with it.

If the zenith distances z_2 of A from B and z_1 of B from A have been measured simultaneously, and if the altitude above sea level of A and B are h_1 and h_2 respectively, we get, the line of vision being considered as a circular arc

$$h_1 \div h_2 = D\left(1 + \frac{h_1 + h_2}{2R}\right) \tan \tfrac{1}{2}(z_1 \div z_2).$$

From this it will appear that the hypothesis of the line of vision being considered a circular arc demands that the difference between the reciprocal simultaneous zenith distances should be constant for the two stations. By making these differences one gets a term for the uncertainty of the determination of k, and this term not only includes the uncertainty of the surveying operations, but also the inaccuracy of the hypothesis.

Below are given the results of eight reciprocal simultaneous zenith distance observations from the Observatory (z_2) and Cairn X (z_1).

The column $z_1 \div z_2$ shows very great oscillations, which are principally due to the variations of the zenith distances (z_1) measured at Cairn X. This might indicate a great inaccuracy in the survey work done by means of the small instrument, as would also

Date	Hour	Temperature		Barometer	Degree of moisture	$z_1 \div z_2$	z_1	z_2	$z_1 + z_2 \div 180°$	k
		O	X	O	O					
11. Aug.	1P35	+ 8.0	+ 9.0	757	49 %	6°17′50″.9	93°10′43″.9	86°52′53″.0	216″.9	0.102
11. —	2P55	+ 9.5	+ 8.8—9.6	756	44	07.2	04.9	57.7	182.6	0.244
24. —	2A40	÷ 2.8	÷ 2.0	760	87	43.5	26.5	43.0	189.5	0.217
24. —	3A50	÷ 2.7	÷ 2.0	760	105	68.3	50.1	41.8	211.9	0.124
27. —	0P35	+ 2.2	+ 3.3	763	64	28.3	24.3	56.0	200.3	0.171
27. —	1P50	+ 3.7	+ 3.0	763	68	16.9	17.7	60.8	198.5	0.178
9. Oct.	0P10	÷ 10.3	÷ 9.3	757	82	51.5	33.3	41.8	195.1	0.192
9. —	1P20	÷ 10.1	÷ 9.5	757	83	45.1	32.6	47.5	200.1	0.172
							Mean..	86°52′50″.2		0.175

be natural. The greatest variation in z_1 on a single day occurs on August 11th; the difference between the two values of z_1 is here 39″. The meteorological conditions during the first series of observations on the above-mentioned day at 1P35 are given in the example on p. 151. During the second series of observations at 2P55 the observation journal shows that the wind changed from WNW to SE, and at the same time the temperature fell quite suddenly from + 9.6 to + 8.8. Besides the observation journal mentions haze and glimmer. The atmospheric conditions on this day have thus been rather unsettled, and consequently there is nothing strange in the fact that the co-efficient of refraction should vary a great deal. However, it is quite obvious on the very face of it, that in case the difference $z_1 \div z_2$ is subject to such great and sudden variations, one cannot attribute any high degree of accuracy to a mean of eight determinations of k, by means of reciprocal, simultaneous observations.

The Observatory—the "Skerry".

To J. P. Jacobsens Ø (see the map, scale 1 : 100,000 of Danmarks Havn and Environs, Pl. II) which in the following will be called the "Skerry", as in the case of Cairn X a large number of zenith distance observations were made, in order to determine the variation of the co-efficient of refraction. In order to make an absolute determination of the co-efficient of refraction above water, we erected on the rocky knoll of the "Skerry" — the top of which was otherwise used as a sighting point, and the altitude of which above the sea was 16.4 m — a stanchion with a similar wooden disc as the one mentioned in the case of Cairn X. The small universal instrument was put up beside the stanchion on the same solid tripod which had been used at Cairn X. The position of the rocky knoll on the "Skerry" was determined by triangulation, and the necessary elements for con-

veying the sights to the reticules of the respective telescopes were measured.

In Fig. 11 O is the Observatory, S the rocky knoll on the "Skerry' and I the position of the universal instrument.

$\angle$ I was 130°31′
OS was determined at 12286.0 m
OI - — - 12282.8 m
IS - — - 5.01 m

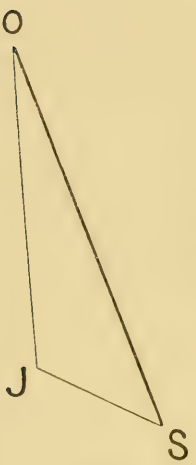


Fig. 11.

The altitude of the centre of the wooden disc in S over I was 0.73 m.

The altitude of the centre of the wooden disc in S over the rock was 1.51 m.

As sighting mark to O was used the middle of the top of the whitewashed wall of the Observatory; this sighting mark lay 0.05 m lower than the reticule of the telescope of the Observatory, and 1.4 m nearer I than the reticule.

By means of the quoted elements and the zenith distances given below the corrections of the zenith distances measured were computed at:

from O to S: $\Delta z_S = + 12''.2$,
from I to O: $\Delta z_0 = \div 0''.8$.

Results of the two observations made on July 20th 1908 by Wegener (the Observatory) and Koch (the "Skerry") in exactly the same manner as those between the Observatory and Cairn X:

Date	Hour	Temperature O	Temperature S	Barometer O	Degree of moisture O	$z_1 \div z_2$	z_1	z_2	$z_1 + z_2 \div 180°$	k
20. July 08	7a40	+ 6.0	+ 2.7	753.7	73 %	0°01′44″.5	90°02′31″.4	90°00′46″.9	198″.3	0.499
—	8a40	+ 7.3	+ 2.3	753.8	65 %	54.7	03 02.6	01 07.9	250.5	0.368
							Mean..	90°00′57″.4		0.434

The value here determined i. e. $k = 0.434$, which corresponds to the two observations of July 20th is of course still more uncertain than the above-mentioned value of k between the Observatory and Cairn X.

Relative determinations.

Besides the reciprocal, simultaneous observations — and the levellings at the horizon, which will be mentioned later on — we

performed, within the period from July 23rd 1907 to July 9th 1908, from the Observatory fifty-three levellings of each of the following four points: Cairn X, Cairn IX, Cairn V and the "Skerry". The object of this was to investigate the variations of the co-efficient of refraction in the various strata of air at different periods.

Cairn X. The distance to the cairn from the Observatory is 7494.5 m; the altitude of the centre of the wooden disc of the cairn is 429 m. The sight thus traverses the strongly marked boundary between the strata at 200 m, but is does not reach so far as to strata of air the temperature of which is lower than the average temperature at the Observatory[1]). The sight exclusively traversed land through the valley which extends east of the Varderyggen (the map, 1 : 100,000, of Danmarks Havn and Environs, Pl. II) at a distance of about 3 km from the coast and divided from the latter by a ridge.

Cairn IX. The distance from the Observatory is 2648.4 m. The altitude of the sighting point on the cairn is 180 m. Thus the sight lies practically altogether in the lower stratum of air, which is characterized by a marked inversion of temperature of about 0.4 degrees as the mean of a year. It passes exclusively across land, but immediately along the coast towards west.

Cairn V is situated in the southern part of Lille Koldewey at a distance of 15780.4 m. The altitude of the sighting mark on the cairn is 90 m. For the last three km nearest the cairn, the sight traverses a low island; otherwise it lies exclusively across water (ice) at an average altitude of 52 m.

The "Skerry". The distance is 12286.0 m. The altitude of the sighting mark 16 m. The sight nearly exclusively traverses water (ice) at an altitude of 14—16 m.

Whenever observations were made, two sets were taken, thus in all 106 sets at every point. The two sets measured within the same series of observations were epitomized into a mean set, which is given under column z in the table below. On the strength of all of these fifty-three mean sets a mean was computed, and the individual deviations from it are given under the column $\Delta z \left(\Delta z = z \div \frac{\Sigma z}{n}\right)$

By differentiation of

$$1 \div k = \frac{R}{D\omega}(z_1 + z_2 \div 180°)$$

and putting $dz_1 = dz_2$ we get

$$dk = \div \frac{2R}{\omega D} dz.$$

[1]) As regards alterations in the meteorological elements with the altitude at Danmarks Havn see Alfred Wegener: Drachen- und Fesselballonaufstiege, Medd. om Grønl. XLII.

Date	Hour	Cairn X z	Cairn X Δz +	Cairn X Δz ÷	Cairn X Δk ÷	Cairn X Δk +	Cairn IX z	Cairn IX Δz +	Cairn IX Δz ÷
		86°51′					86°26′		
9. July 1908...	2P30	16″.3		10″.9		90	30″.1	4″.4	
23. — 1907...	10a50	23.1		4.1		34	24.7		1″.0
24. — — ...	4P40	26.5		0.7		6	27.2	1.5	
25. — — ...	7P45	24.5		2.7		22	17 1		8.6
26. — — ...	7P00	35.8	8.6		71		27.6	1.9	
27. — — ...	9a45	11.1		16.1		133	18.2		7.5
— — — ...	11P00	21.2		6.0		50	30.8	5.1	
28. — — ...	11a00	26.6		0.6		5	25.3		0.4
29. — — ...	10P00	24.7		2.5		21	24.6		1.1
30. — — ...	8P40	24.1		3.1		26	23.0		2.7
2. Aug. — ...	1P30	25.8		1.4		12	29.7	4.0	
8. — — ...	10P10	25.8		1.4		12	25.8	0.1	
9. — — ...	9a00	26.7		0.5		4	18.6		7.1
11. — — ..	2P00	24.8		2.4		20	22.3		3.2
12. — — ...	8P30	17.4		9.8		81	18.2		7.5
23. Aug. — ...	2P30	41.1	13.9		115		32.7	7.0	
— — — ...	8P30	28.3	1.1		9		27.4	1.7	
24. — — ...	3a15	21.0		6.2		51	14.6		11.1
— — — ...	10a40	30.0	2.8		23		23.2		2.5
27. — — ...	1P10	34.6	7.4		61		28.4	2.7	
— — — ...	8P00	20.4		6.8		56	23.8		1.9
28. — — ...	5a40	23.0		4.2		35	24.2		1.5
31. — — ...	11a00	32.3	5.1		42		28.1	2.4	
8. Sept. — ...	2P50	35.6	8.4		70		27.4	1.7	
11. — — ...	10a00	31.1	3.9		32		31.1	5.4	
— — — ...	2P50	37.0	9.8		81		28.6	2.9	
— — — ...	8P20	16.2		11.0		91	24.4		1.3
12. — — ...	9a30	35.2	8.0		66		27.4	1.7	
13. — — ...	7P00	26.1		1.1		9	27.2	1.5	
14. — — ...	5a40	18.8		8.4		70	24.7		1.0
— — — ...	7a10	27.8	0.6		5		22.5		3.2
— — — ...	11a10	39.4	12.2		101		33.2	7.5	
— — — ...	3P10	35.7	8.5		70		29.0	3.3	
— — — ...	7P20	19.9		7.3		60	21.1		4.6
15. — — ...	3P20	34.4	7.2		60		29.8	4.1	
17. — — ...	2P50	35.9	8.7		72		27.6	1.9	
9. Oct. — ...	0P40	22.6		4.6		38	25.9	0.2	
10. — — ...	9a40	24.4		2.8		23	25.7	0.0	0.0
— — — ...	1P50	27.4	0.2		2		24.2		1.5
21. — — ...	8a50	03.2		24.0		199	17.8		7.9
— — — ...	1P30	16 8		10.4		86	19.4		6.3
31. May 1908...	10a10	05·9		21.3		176	19.6		6.1
9. June — ...	7P00	28.9	1.7		14		32.4	6.7	
15. — — ...	2P10	44.2	17.0		141		31.6	5.9	
— — — ...	6P10	37.7	10.5		87		40.2	14.5	
— — — ...	10P10	30 5	3.3		27		07.4		18.3
16. — — ...	2a00	28.1	0.9		7		23.7		2.0
— — — ...	6a10	35.7	8.5		70		25.1		0.6
— — — ...	10a30	35.3	8.1		67		24.0		1.7
— — — ...	2P00	35.1	7.9		65		28.4	2.7	
18. — — ...	9a00	30.1	2.9		24		29.8	4.1	
20. — — ...	6P50	28.3	1.1		9		35.1	9.4	
22. — — ...	1P20	30.3	3.1		26		30.0	4.3	
	Mean...	86°51′ 27″.2					86°26′ 25″.7		

Cairn V Δk ÷	Cairn V Δk +	Cairn V z	Cairn V Δz +	Cairn V Δz ÷	Cairn V Δk ÷	Cairn V Δk +	Skerry z	Skerry Δz +	Skerry Δz ÷	Skerry Δk ÷	Skerry Δk +
		89°					89°				
103		46′33″.3	10″.5		41		60′09″.6		47″.9		242
	23	45 35.3		47″.5		187	59 58.1		59.4		300
35		46 48.0	25.2		99		61 40.2	42″.7		216	
	201	45 59.6		23.2		91	60 26.6		30.9		156
44		46 31.4	8.6		34		61 16.4	18.9		95	
	176	45 25.2		57.6		226	59 25.0		92.5		467
119		45 59.6		23.2		91	57 40.8		196.7		993
	9	46 00.2		22.6		89	60 21.6		35.9		181
	26	46 22.6		0.2		1	60 55.5		2.0		10
	63	45 32.6		50.2		197	59 09.4		108.1		546
94		46 25.8	3.0		12		60 51.8		5.7		29
2		46 36.5	13.7		54		60 52.8		4.7		24
	166	45 43.5		39.3		154	61 34.4	36.9		186	
	75	45 40.6		42.2		166	59 46.4		71.1		359
	176	45 51.6		31.2		123	61 25.0	27.5		139	
164		46 43.9	21.1		83		61 41.0	43.5		220	
40		46 21.6		1.2		5	61 07.5	10.0		50	
	260	45 53.2		29.6		116	60 44.2		13.3		67
	58	46 22.6		0.2		1	61 10.8	13.3		67	
63		46 48.2	25.4			109	61 13.0	15.5		78	
	44	45 55.1		27.7	100		60 58.2	0.7		4	
	35	46 38.9	16.1		50		61 24.5	27.0		136	
56		46 46.8	24.0		94		61 37.0	39.5		200	
40		46 47.0	24.2		95		61 43.0	45.5		230	
126		46 56.6	33.8		133		61 49.8	52.3		264	
68		46 37.2	14.4		57		61 45.0	47.5		240	
	30	46 53.3	30.5		120		61 47.6	50.1		253	
40		46 40.4	17.6		69		61 46.4	48.9		247	
35		46 45.5	22.7		89		61 35.6	38.1		192	
	23	46 31.6	8.8		35		61 41.6	44.1		223	
	75	46 43.9	21.1		83		61 39.4	41.9		212	
176		46 57.8	35.0		138		61 49.5	52.0		262	
77		46 47.6	24.8		97		61 45.3	47.8		241	
	108	46 30.6	7.8		31		61 27.6	30.1		152	
96		46 46.8	24.0		94		61 45.8	48.3		244	
44		46 51.0	28.2		111		61 40.2	42.7		216	
5		46 45.8	23.0		90		61 29.6	32.1		162	
0	0	46 35.8	13.0		51		61 26.6	29.1		147	
	35	46 41.4	18.6		73		61 42.0	44.5		225	
	185	46 35.2	12.4		49		61 31.6	34.1		172	
	148	46 29.8	7.0		28		61 33.9	36.4		184	
	143	46 33.3	10.5		41		61 34.4	36.9		186	
157		46 46.4	23.6		93		61 31.2	33.7		170	
138		46 47.1	24.3		96		61 11.0	13.5		68	
340		46 38.8	16.0		63		60 45.5		12.0		61
	429	44 29.5		113.3		445	56 56.2		241.3		1203
	47	46 12.0		10.8		42	60 05.2		52.3		264
	14	45 52.0		30.8		121	58 39.8		137.7		705
	40	46 23.2	0.4		2		60 32.8		24.7		125
63		46 17.0		5.8		23	61 05.7	8.2		41	
96		46 10.8		12.0		47	60 29.8		27.7		140
220		46 01.1		21.7		85	61 10.6	13.1		66	
101		46 26 4	3.6		14		61 15.0	17.5		88	
		89° 46′ 22″.8					90° 00′57″.5				

This formula was used to compute the deviations of the co-efficient of refraction from the mean value. These deviations are entered in the table under Δk in units of the third decimal place.

In the case of Cairn X and the "Skerry" the correction of the values of the co-efficient of refraction, which had already been determined by means of reciprocal, simultaneous observations, was likewise computed from the formula $dk = + \frac{2R}{\omega D} dz$. In order that this might occur, the values which had been determined by reciprocal observations of the zenith distances of the reticule of the little instrument, had to be conveyed to the centre of the wooden disc at Cairn X and to the top of the rocky knoll on the "Skerry", by means of the correction $\div 1'24''.8$ and $+ \omega \frac{1.51\text{ m} \div 0.73\text{ m}}{12286\text{ m}} = + 16''.5$.

Besides the two thus determined values of the co-efficient of refraction we further — as given in the following — computed a value corresponding to a point of the sea horizon. As mean values of the observations to Cairn X, to the "Skerry" and the said point of the sea horizon we have:

$$\begin{aligned} &\text{for Cairn X} && k_m^{\text{X}} = 0.160, \\ &\text{- the "Skerry"} && k_m^{\text{S}} = 0.516, \\ &\text{- Horizon II} && k_m^{\text{II}} = 0.584. \end{aligned}$$

Absolute determinations at the sea horizon.

The levellings at the sea horizon were undertaken in three different fixed azimuths. The distance to the points observed may be computed from the known formula

$$D = \sqrt{\frac{2R}{1 \div k}} \sqrt{h}$$

However, one may deduce a still simpler term in which k is not included, through the following argument:

If the levelling at the sea horizon is considered as the one observation in a reciprocal, simultaneous zenith-measuring, it follows, as a matter of course, that the other imaginary levelling gives a zenith distance equal to 90°.

For the difference of altitude between two points, in which a reciprocal, simultaneous observation of the zenith distance is undertaken one gets:

$$h_1 \div h_2 = D \tan \tfrac{1}{2} (z_1 \div z_2)^{1})$$

[1]) Approximation for $h_1 \div h_2 = D \left(1 + \frac{h_1 + h_2}{2R}\right) \tan \frac{1}{2} (z_1 \div z_2)$.

If we put $h_2 = 0$ and $z_2 = 90°$ we get

$$h = D \tan \tfrac{1}{2}(z \div 90°) \text{ or}$$
$$D = h \cot \tfrac{1}{2}(z \div 90°)$$

The mean value of all the zenith distances at the horizon is 90°04′04″, to which corresponds D = about 23.5 km. The greatest value of zenith distances to the horizon is 90°06′31″, to which corresponds D = about 14.7 km.

The three points at which the levellings were made are in the following designated as I, II and III.

The sight at I passed between J. P. Jacobsens Ø (the "Skerry") and Lille Koldewey, a couple of hundred metres in an easterly direction past Kap Christian (see the map: 1 : 100,000 of Danmarks Havn and Environs, Pl. II). The refraction was here often very markedly influenced by the nearness of the land. In particular the horizon often appeared oblique, in that it lay deeper towards Lille Koldewey (see Fig. 20, p. 194).

The sight at II passed between J. P. Jacobsens Ø and Maroussia and in such a manner that the distances from the sight to J. P. Jacobsens Ø and Østre Havnenæs (headland on the east side of the harbour entrance[1]) were equally great. As far as this sight was concerned, the influence of the nearness of the land was as small as possible.

The sight at III passed in a south easterly direction across Yderbugten (the outer bay). For the first 7 to 8 km this sight passed across country or between the skerries in Yderbugten. It was often distinctly influenced by running closely across the country; moreover the land prevented us from seeing the sea horizon, when it lay deepest.

In spite of the abnormal conditions at I and in particular at III, the levellings at these points are, it is to be presumed, of some interest, and so I have included them in the subsequent table. On the other hand, I have not chosen to compute the co-efficient of refraction of the series of observations at I and III, but only as far as the levellings at II are concerned. To compute k the formula

$$1 \div k = \left(\frac{z \div 90°}{\omega}\right)^2 \frac{R}{2h}$$ [1])

[1]) The formula may be deduced from the familiar terms of reciprocal, simultaneous zenith distances:

$$1 \div k = \frac{R}{D\omega}(z_1 + z_2 \div 180°) \text{ and}$$
$$h_1 \div h_2 = D \tan \tfrac{1}{2}(z_1 \div z_2) = D\frac{(z_1 \div z_2)}{2\omega}$$

by putting $z_2 = 90°$, $h_2 = 0$ and $h_1 = h$.

has been used. From the latter it appears that there should be a maximum value of k corresponding to $z = 90°$, i. e. $k = 1$. The observations at the horizon II, however, show three cases, where $z < 90$, and to this must necessarily correspond values $k > 1$.

It must be borne in mind that the computation of k rests upon the basis of the refraction being the same at all points of the sight line. In this manner the line of vision at the horizon becomes an arc of a circle which touches the sight line and the surface of the sea, and the radius of which must consequently be greater than R, when the sight line turns the concavity downwards.

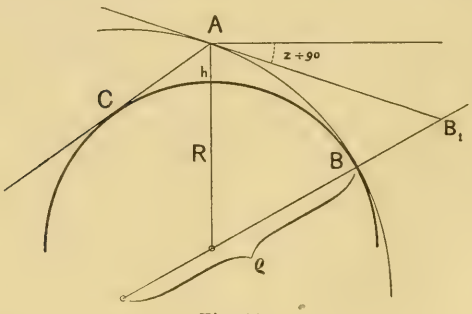


Fig. 12.

In Fig. 12 the earth is looked upon as a sphere, with the radius R, whereas the line of vision is considered an arc of a circle with the radius ρ. The geometrical significance of k is $k = \frac{R}{\rho}$; the line of vision AB to which the sight line AB_1 makes a tangent, represents a normal case.

In the case of $\rho = \infty$ the line of vision becomes a straight line — AC in Fig. 12. To this corresponds the value $k = 0$, or in the case of the zenith distance from the Observatory in Danmarks Havn $z = 90°07'10''$. In the case of still greater zenith distances k would be negative i. e. the line of vision would turn the concavity upwards. This has not occurred in the case of the levellings at the sea horizon, whereas it undoubtedly occurs in the case of those undertaken at Cairn IX.

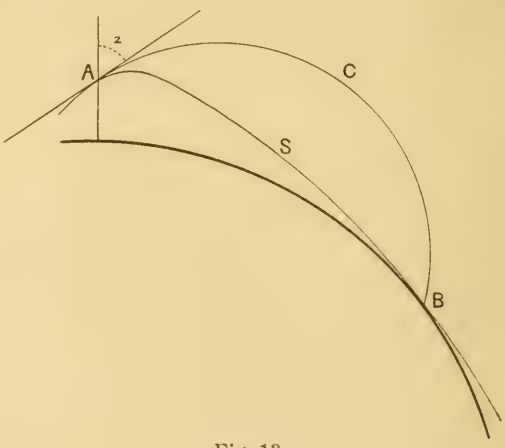


Fig. 13.

In the case of $\rho < R$ the theoretical line of vision ACB (Fig. 13) becomes more curved than the surface of the earth. It will, however, appear at once from Fig. 13 that the course of the theoretical line of vision excludes the seeing of the horizon. In order that this may be possible it is an absolute necessity that the line of vision should touch the surface of the sea, i. e. it must e. g. have a course like the one of ASB in Fig. 13. The

line of vision ASB corresponds to an upward mirage, and such a one must always be found, when a levelling at the sea horizon gives $z < 90°$.

In the case of $z \leq 90°$, the presumption on which the formula

$$1 \div k = \left(\frac{z \div 90°}{\omega}\right)^2 \frac{R}{2h}$$

was based fails altogether. In these cases it can only be used for the purpose of computing k by insisting on the very plausible claim that dk should not change signs with $z = 90°$; in other words, in the case of $z < 90°$ the formula must be

$$1 \div k = \div \left(\frac{z \div 90°}{\omega}\right)^2 \frac{R}{2h}$$

With a telescope altitude as small as that of the Observatory, 13.89 m, there might be a question of applying a correction for the tidal movement on the levellings at the horizon. From tidal observations at Maroussia it appeared that the difference between the flow and ebb may here be estimated at about 1 m, and also that the times of high water at Maroussia and Danmarks Havn were the same [1]). It would consequently be possible to apply a rather uncertain correction for the tidal movement.

From $1 \div k = \left(\frac{z \div 90°}{\omega}\right)^2 \frac{R}{2h}$ we get for the angle of depression

$$z \div 90° = \omega \sqrt{\frac{2\,(1 \div k)}{R} \cdot h}$$

from which in its turn $dz = \omega \sqrt{\frac{(1 \div k)}{2hR}} \cdot dh.$

As the telescope altitude in the Observatory corresponds to the mean water level at Danmarks Havn for 1907, dh as a maximum may be put at $^1/_2$ m. Suppose that we further put $k = 0.584$ (the mean value of II) we get $dz = \omega \sqrt{\frac{0 \cdot 416}{8hR}} =$ about 6″.

In the face of the uncertainty of the observations at the sea horizon there will evidently be no reason to apply such an immaterial and uncertain correction, which may furthermore not be supposed to influence the determination of the mean value of k, but only of the single values.

In the table below the zenith distances measured in the directions I, II and III are given. Like the preceding one this table is divided by means of horizontal lines into three sections, corresponding

[1]) A. Trolle: Hydrographical observations from the Danmark-Expedition, Medd. om Grønland XLI, p. 417.

Levellings at the sea horizon.

Date	Hour	I			II						III		
		z	Δz		z	Δz		k	Δk		z	Δz	
			+	÷		+	÷		÷	+		+	÷
		89°			89°						89°		
9. July 1908. .	2p50	62′07″		125″	61′59″		125″	0.923		339	62′04″		112″
27. — 1907. .	11p20	59 08		304	58 13		351	1.062		478	60 15		221
28. — — . .	11a00	61 40		152	61 31		153	0.955		371	63 35		20
29. — — . .	10p40	63 51		21	63 23		41	0.779		195	64 06	10	
30. — — . .	9p10	60 38		214	60 29		215	0.995		411	62 36		80
2. Aug. — . .	2p10	62 55		77	61 12		172	0.972		388	62 00		116
					(62 56)						(63 30)		
9. — — . .	9a50	63 28		44	62 15		109	0.901		317	64 54	58	
					(63 07)								
					(64 27)								
12. — — . .	9p00	62 56		76	61 28		156	0.958		374	63 10		46
23. Aug. — . .	3p00	66 08	116		65 59	115		0.303	281		[67 08]	[192]	
— — — . .	9p10	64 23	11		64 22	18		0.629		45	64 04	8	
24. — — . .	4a20	64 27	15		64 24	20		0.623		39	64 27	31	
— — — . .	11a30	64 31	19		65 34	90		0.396	188		65 04	68	
27. — — . .	0p20	63 40		32	63 25		39	0.773		189	64 04	8	
— — — . .	8p40	63 02		70	62 53		71	0.838		254	62 35		81
28. — — . .	6a20	65 29	77		65 24	80		0.432	152		64 30	34	
31. — — . .	10a40	65 31	79		65 22	78		0.439	145				
8. Sept. — . .	3p30	65 38	86		65 30	86		0.411	173		[65 51]	[115]	
11. — — . .	9a40	66 31	139		66 18	134		0.227	357		[66 46]	[170]	
					(67 06)								
					(67 55)								
— — — . .	2p20	66 27	135								[67 05]	[189]	
		(68 07)			(68 16)								
— — — . .	8p40	66 15	123		66 27	143		0.190	394		63 19		37
12. — — . .	9a00	66 01	109		66 02	118		0.291	293		65 03	67	
13. — — . .	7p20	65 22	70		65 12	68		0.473	111		63 08		48
14. — — . .	3a30	65 10	58		65 16	72		0.460	124		62 54		62
— — — . .	7a40	66 06	114		66 15	131		0.239	345		64 45	49	
— — — . .	11a30	66 24	132		66 30	146		0.177	407		[66 51]	[175]	
— — — . .	3p30	66 12	120		66 14	130		0.243	341		65 35	99	
— — — . .	7p40	65 07	55		64 52	48		0.539	45		62 28		88
15. — — . .	3p40	66 20	128		66 31	147		0.173	411		64 38	42	
17. — — . .	3p20	65 20	68		65 31	87		0.407	177		64 42	46	
9. Oct. — . .	11a50	65 22	70		65 40	96		0.374	210		63 00		56
10. — — . .	10a00	65 58	106		66 07	123		0.271	313				
— — — . .	2p20	66 22	130		66 24	140		0.202	382				
21. — — . .	9a30	65 27	75		66 28	144		0.186	398		65 01	65	
— — — . .	2p00	64 28	16		66 21	137		0.215	369		63 19		37
31. May 1908. .	11a50	65 53	101		65 50	106		0.337	247				
9. June — . .	7p20	64 44	32		64 19	15		0.637		53	65 04	68	
15. — — . .	2p30	64 26	14		64 12	8		0.656		72	65 09	73	
— — — . .	6p30	62 34		98	62 48		76	0.847		263	63 08		48
— — — . .	10p30	56 31		461	56 39		445	1.219		635	56 21		455
16. — — . .	2a20	59 53		259	59 21		283	1.008		424	59 51		245
— — — . .	6a30	61 13		179	60 51		193	0.986		402	61 52		124
— — — . .	10a40	64 00		12	64 05	1		0.675		91	64 54	58	
— — — . .	2p20	64 16	4		63 48		16	0.719		134	64 40	44	
18. — — . .	9a20	63 45		17	63 31		33	0.759		174	65 05	69	
21. — — . .	7p00	64 27	15		64 22	18		0.629		45	65 24	88	
22. — — . .	1p40	63 12		60	63 28		36	0.766		182	64 41	45	
Mean. . .		90°04′12″			90°04′04″			0.5843			[90°03′56″]		

to the periods July 9th to August 12th, August 23rd to October 21st (autumn) and May 31st to June 22nd. In the same manner as in the table on pp. 156—157 we have made the terms $\Delta z = z - z_m$ where z_m stands for the mean value of all the zenith distances in the said direction; but whereas Δz in the earlier table gives the direct impression of the variation of the co-efficient of refraction, here where $1 - k$ is proportional to the quadrate of the angle of depression it only gives a direct impression of the variation of the zenith distance. As to direction II k is computed by every single observation, after which Δk is made from $\Delta k = k - k_m$ (Δk is indicated in units of the third decimal place).

When on account of mirages there were several horizons to choose between, it was as a rule impossible to decide which was the "real one", and which one or ones must be characterized as mirages. This is owing to the complicated nature of the mirage, which often only appears in the shape of a confused column structure intersected by one or more horizontal lines, more or less effaced. The column structure and the horizontal lines will at times disappear altogether, in which case the existence of the mirage can only be proved by the fact that an observation gives $z < 90°$. The otherwise rather common, simple case of an upward mirage where the reflection of the sea horizon appears as a horizontal streak, which may elevate itself about $^1/_4$ degree above the normal position of the horizon, has not occurred during the observations. On the other hand, we have in the course of the observations had several cases of a downward mirage, where the reflection of the sky appeared as a stratum of air under the real sea horizon, and so created a false and lower lying horizon. An example of this are the observations in the directions I and II on September 11th at 2P.20 (see Fig. 22, p. 195). As regards direction II the real sea horizon was just discernible with the naked eye, but it could not be observed in the telescope. In the table below the zenith distance given in direction II is to the false horizon; the computation of this zenith distance would have given k negative, but would have been illogical, as the line of vision does no longer, as presupposed in the formula, touch the surface of the sea, but crosses the latter. In all the cases now before us there was in reality no other expedient open to us but to consider the false horizon as the real one. In the cases where the lower lying ones were sufficiently clearly defined to admit of an observation, I have in the table given the zenith distances in parenthesis.

In the case of direction III it happened on several occasions that the sea horizon lay deeper than the land which the sight tra-

versed. In these cases I have given the zenith distance of the land and the Δz corresponding to it in brackets.

Critical remarks on the observations.

The observations had to be made incidentally, and they also bear indisputable witness to an unfortunate lack of systematic accomplishment. The chief lack is, I suppose, that there are no observations whatsoever from the winter and the greater part of the spring. This was not to be avoided, partly because the darkness prevented us from seeing the cairns during the winter, and partly because in the period from March to June all our strength was required for very far-going sledge-trips. The observations only cover the period from May 31st to October 21st, in other words, not quite five months, but on the other hand the observations within this period are so numerous, that in spite of their casual distribution they are able to give a fairly complete idea of the conditions of refraction.

First and foremost it is obvious how extreme are the mean values of k determined by the Danmark-Ekspedition, as compared with the European determinations. In demonstration I am going to insert the determinations of the Danmark-Ekspedition in the series of various determinations of the co-efficient of refraction, given by Zachariae[1]):

Landestriangulation, sights in land	0.1175
Struve	0.1237
Baeyer, sights in land	0.1239
Caraboeuf	0.1285
Landestriangulation, sights near the coast	0.1292
Gauss	0.1306
Dépôt de la Guerre	0.1350
Baeyer, sights near the coast	0.1362
Ostpreussische Gradmessung	0.1370
Danmark-Ekspedition: sights across country	*0.160*
Delambre	0.1678
Baeyer, sights across water	0,1753
Danmark-Ekspedition, sights across water	*0.516*
Danmark-Ekspedition, sights across water to the sea horizon	*0.584*

The oscillations to which the co-efficient of refraction is subject, are in the case of the Danmark-Ekspedition considerably greater than

[1]) G. Zachariae: De Geodætiske Hovedpunkter og deres Koordinater, Kjøbenhavn 1876, p. 213.

those generally indicated in other places. This is perhaps more apparent than real. The determination of the co-efficient of refraction is generally a secondary result of big levelling works, where it follows as a matter of course that efforts have been made to avoid conditions of refraction, which deviated very much from the normal. As far as the Danmark-Ekspedition was concerned the chief object was a general investigation of the terrestrial refraction, and here the abnormal cases could only claim our notice to the same extent as the normal ones.

From the above-mentioned work of ZACHARIAE I am going to quote a few extreme single values of k for comparison with the corresponding ones given by the Danmark-Ekspedition.

	Maximum	Minimum
Delambre	$+0.595$	$\div 0.007$
Ostpreussische Gradmessung	$+0.154$	$+0.126$
Levelling Swinemünde—Berlin	$+0.267$	$+0.083$
Küstenvermessung	$+0.388$	$+0.096$
Landestriangulation	$+0.173$	$+0.058$
Gauss	$+1.208$	$\div 0.114$
Danmark-Ekspedition:		
Levelling at Cairn X	$+0.359$	$+0.019$
— — IX	$k_m^{IX}+0.427$	$k_m^{IX}\div 0.340$
— — V	$k_m^{V}+0.445$	$k_m^{V}\div 0.138$
— at "Skerry"	$+1.720$	$+0.252$
— - Horizon II	$+1.219$	$+0.173$

I have not had the opportunity of acquainting myself with the determinations made by Gauss, but judging by the great difference between the maximum and minimum values of k I think it most likely that here — as in the case of the Danmark-Ekspedition — a general knowledge of the terrestrial refraction was the object of the investigation. The minimum value given by Gauss, $\div 0.114$, corresponds quite well with the minimum value of Cairn IX, in that k_m^{IX}, as will be shown below may be put at 0.237. The extremely high maximum value of the "Skerry" is an isolated one. The second greatest value, also in the case of the "Skerry" is 1.509, and after that comes the maximum value 1.219 given for Horizon II.

The mean value of the co-efficient of refraction at the sea horizon is determined as the mean of forty-five single values, distributed over the period 31st May to 21st October. Within this period $k_m^{II} = 0.584$ may be considered a fairly reliable value. In contradistinc-

tion the mean value to Cairn X and to the "Skerry", k_m^X and k_m^S must, as mentioned above, be considered very uncertain. The best plan will consequently be to look at once for a control of the determinations made. The basis of the continued discussion will then appear, of its own accord, as the result of this research.

For the co-efficient of refraction at a given point we have the following term[1]):

$$\varkappa = 0.000293 \times \frac{b}{760} \times \frac{273}{T} \times \frac{g}{G} \times R \times F, \text{ where}$$

$$F = \frac{\tau}{T} + \frac{1 \div \frac{3e}{8b}}{7993} \times \frac{273}{T} \times \frac{g}{G} \text{ and}$$

$$\frac{g}{G} = 1 \div 0.00265 \cos 2\varphi \div \frac{2h}{R}$$

In this term b is the pressure of the air in millimetres, reduced to 0°, T the absolute temperature $= 273° + t°$, g the acceleration of gravity for the place in question, G the acceleration of gravity in 45° latitude at the level of the sea, R the radius of curvature of the ellipsoid, τ the variation of temperature per metre $\left(\frac{dT}{dh}\right)$, e the pressure of the aqueous vapour in millimetres, φ the geographical latitude and h the altitude above the level of the sea.

In the case of $\varphi = 76°46'$ $\frac{g}{G}$ oscillates between 1.0024 ($h = 0$) and 1.0023 ($h = 429$ m), consequently in the case of computation with a four-placed table $\frac{g}{G}$ becomes $= 1.002$ in all instances.

When computing the factor F we are confronted with a difficulty, in that our knowledge of the pressure of the aqueous vapour is rather uncertain. As far as the Observatory is concerned, the pressure may be computed from the percentage of moisture; but as the term for $\varkappa$ is here to be used to compute a mean value of the co-efficient of refraction corresponding to the whole of the line of vision, one ought to know the mean value of e corresponding to the whole line. The relative moisture at Danmarks Havn varies between 40 % and 100 %; in the case of the months June to October, which here may be taken into consideration, all of the mean values of the months are somewhere about 70—80 %. Above water the percentage of moisture is probably somewhat greater. The variation of moisture with the altitude is immaterial to this research. If we

[1]) F. R. Helmert: Die mathematischen und physicalischen Theorien der höheren Geodæsi, II Teil, p. 577.

put the percentage of moisture at 70, the temperature at $+2$, and the pressure of the air at 750 mm we get

$$\div \frac{3\,e}{8\,b} = \div \frac{3 \times 5.29}{8 \times 750} \times 0.7 = \div 0.0018.$$

In this case we consequently get:

$$\left(1 \div \frac{3\,e}{8\,b}\right) \frac{g}{G} = (1 \div 0.002)\,(1 + 0.002) = 0.999996.$$

Even if we presuppose exceptionally unfavorable conditions, the error of putting $\left(1 \div \frac{3\,e}{8\,b}\right) \frac{g}{G} = 1$ will not exceed one unit in the third decimal place, which error is quite insignificant in the face of the uncertainty which characterizes the determination of τ (the variation of temperature by the metre).

In this manner we achieve an essential simplification of the computation of $\varkappa$. If we put $\log R = 6.8059$ we get

$$\varkappa = 674.8 \cdot \frac{b}{T^2}\,(\tau + 0.0342).$$

In order to compute $\varkappa$ we must thus know the quantities b, T and τ. In the case of altitudes up to 200 m and 500 m a mean value of T and τ may be computed for the moments at which kite- or balloon-ascensions took place near Danmarks Havn, whereas b may be computed by means of T and the pressure at the level of the sea, which appears from the meteorological observations undertaken day by day. In the unfortunately rather few cases, where the levellings at the cairns IX and X are undertaken simultaneously with kite- or balloon-ascensions, we thus have a means to control the determinations of k by computing $\varkappa$.

As far as the levellings at the "Skerry" are concerned, the state of things is more favorable. Simultaneously with eighteen of these levellings measurements of temperature were made at the surface of the ice and in the crow's nest of the ship of the expedition. These latter were carried out at an altitude of 30 m above the level of the sea, which as far as the determination of τ is concerned practically coincides with the fact that the line of vision from the Observatory to the "Skerry" lies at an altitude of between 14 and 16 m.

The certainty of the determination of τ plays a vital part in the determination of $\varkappa$; the uncertainty of b and T will in this case be rather immaterial. If b and T are looked upon as constant and equal to 750 mm and 273° respectively we get

$$d\varkappa = \frac{674.8 \times 750}{273^2}\,d\tau = 6{,}8\,d\tau.$$

If we put $d\tau = 0.001$, dz becomes $= 0.007$.

The error of the determinations of τ must generally be supposed to exceed 0.001 degrees and will even in unfavorable cases now and then exceed 0.01 degrees. The little examination shows that when computing the single values of z one can scarcely rely upon the second decimal; the third decimal can in any case only be considered as approximate.

Before passing on to a comparison between the values of k and z I shall premise a few remarks about the value of a comparison of this kind.

Towards the end of August 1907 a further examination of the levellings made till then at the cairns V, IX, X and at the "Skerry" showed that the observations, particularly on certain days, presented very marked irregularities, which appeared as purely spontaneous changes in the correction of the zenith point. That the zenith distances were subject to rapid and great variations, experience had tought us long before; the very marked apparent and quite temporary changes in the correction of the zenith point were therefore looked upon as an indication that the zenith distance had undergone a corresponding change in the period between the two pointings "telescope right" and "telescope left". In order to investigate this more closely we resolved that the observer after the pointing of the object should immediately read the level of the vertical circle; after that the microscopes and then again the level. Finally the direction of the telescope was to be controlled, before the instrument was reversed or a new object pointed. In this manner we guarded ourselves against a possible alteration of the zenith distance expressing some sudden change in the adjustment of the instrument. It now turned out that the zenith distance was often perceptibly altered during the short duration of the reading of level and microscopes. On a few occasions we also saw the object shooting quite suddenly above the middle horizontal thread or sinking below it. The change in the zenith distance might be purely temporary and last for a few seconds, but it might also extend over several minutes or a longer period. This kind of change in the zenith distance we called "vertical movement", and in the observation journal we indicated its intensity according to an estimate, 0, 1, 2, and 3, where 0 meant that the observation of the object with each test had proved unchanged, whereas 3 indicated the highest intensity of "vertical movement". It is an obvious fact that this estimate must be rather uncertain. The "vertical movement" is tantamount to a change in the refraction angle[1]) and is proportional to the distance. A rough

[1]) The angle between the sight line and the straight line between telescope and object.

estimate of the „vertical movement" would therefore result in the latter being considered as strongest and most frequently occurring in the case of objects farther away, which also appears from the observation journal.

From the observation journal it appears that out of thirty-two observation series the designation 0 (absolute rest over all objects) was only given to six, whereas in the case of twenty-six the designation 0—3 was used, generally varied in the case of the different objects.

From what has been indicated it appears that the co-efficient of refraction, k, is generally subject to sudden variations, which may become very considerable. On a few occasions, when the zenith distance at the control turned out to be perceptible, a new observation was made by means of the slow moving screw, and so the vertical movement was measured. On the strength of this it becomes possible to compute the corresponding change in k. As an example I shall here give three instances of very considerable variations of k within a period of about $^1/_2$ minute.

Vertical movement.

Levelling at	Intensity estimated	measured at	Δk
Cairn IX — Sept. 14th 07 at 11^a10 ...	1	5″.5	0.130
Cairn X — Oct. 21st 07 at 8^a50	3	15″.5	0.128
Cairn V — June 15th 08 at 10^p10 ..	3	27″	0.106

The causes of the vertical movement will be mentioned later on; here attention is only to be directed to the fact, that in the face of such extensive and momentary changes in k, one cannot in the single cases expect any agreement between the values of k and $\varkappa$. On the other hand one may, when a great number of nearly simultaneous values of k and $\varkappa$ are forthcoming, count on a reasonable agreement between the means.

As k must be considered a mean value of the co-efficients of the refraction in the line of vision in question, the values of b, τ and T, which are necessary for the computation of $\varkappa$, must also be determined as mean values of this line. In the cases where simultaneously with the levellings kite- and balloon-ascensions have been made, it has been possible to form a fairly reliable estimate of these quantities corresponding to the lines of vision at the cairns IX and X. The manner of proceeding in such cases has been as follows:

By means of the temperature of the air at the Observatory as

well as at an altitude of 200 and 500 metres[1]) the temperature of the altitudes of 180 m (the sighting point on Cairn IX) and 429 m (the sighting point on Cairn X) was determined by simple interpolation. In case t_{14}, t_{180}, t_{200} and t_{429} indicate the temperatures in centigrade at the Observatory, as well as in the altitudes 180 m, 200 m and 429 m, T_{IX} was estimated at $273° + {}^1/_2 (t_{14} + t_{180})$ whereas T_X on account of the boundary between the strata at 200 m was computed from $T_X = 273 + {}^1/_4 (t_{14} + 2\,t_{200} + t_{429})$. With correspondent designation we had $\tau_{IX} = (t_{180} \div t_{14}) : 166$ and $\tau_X = (t_{429} \div t_{14}) : 415$. The atmospherical pressures b_{IX} and b_X were computed by means of the pressure of the air, b_0, at the level of the sea and reduced to 0°[2]), by using the simple formula for barometrical measurement of altitudes

$$h = 18400\ (1 + \alpha\, t)\ \log \frac{b_0}{b}$$

in other words without making allowance for the terms of correction of the pressure of aqueous vapour, the geographical latitude and the mean altitude[3]). As an example may be quoted that for the sight at Cairn IX are get:

$$\log b_{IX} = \log b_0 \div \frac{97 \times 273}{18400 \times T_{IX}}.$$

As absolute determinations of k have not been made between the Observatory and Cairn IX, I have from the mean value for $\varkappa$ and the single values formed $\Delta\varkappa = \varkappa \div \varkappa_m$, and for comparison I have in the table below given Δk with the same value as in the table p. 157. Seeing that $\Delta\varkappa$, as it will appear, only refers to a mean value of ten single values, whereas Δk is formed by comparison with the mean of all fifty-three determinations, the juxtaposition of $\Delta\varkappa$ and Δk in the table is not strictly logical. The correction which should have been applied on the Δk's in order to remedy this drawback is, however, only + 0.003, which quantity, as a glance at the table will show, is of no importance to the direct comparison.

[1]) See: Alfred Wegener: Drachen- und Fesselballonaufstiege; Danmark-Ekspeditionen til Grønlands Nordøstkyst 1906—1908, Medd. om Grønland Bd. XLII.

[2]) See: Alfred Wegener: Meteorologische Terminbeobachtungen am Danmarks Havn; Medd. om Grønland Bd. XLII.

[3]) The complete formula is as follows:

$$h_1 \div h_2 = 18400 \log \frac{b_1}{b_2} (1 + \alpha\, t) \left(1 + 0.377\ \frac{e}{b}\right)(1 + 0.000265 \cos 2\varphi)\left(1 + \frac{h_1 + h_2}{R}\right)$$

where $\frac{e}{b}$ is the proportion between pressure of vapour and pressure of air as mean value in the column of air considered; t is the mean temperature in centigrade and R the radius of curvature.

Refraction conditions in the line of vision Observatory—Cairn IX.

Date	Hour	b_{IX}	$\tau_{IX} + 0.0342$	T_{IX}	$\varkappa$	$\Delta\varkappa$	Δk
12. Aug.	8P30	746.5	0.0391	278.4	0.254	+ 0.020	+ 0.176
27. —	8P00	754	0.0433	274.6	0.293	+ 0.059	+ 0.044
31. —	11A00	756	0.0331	272.6	0.227	÷ 0.007	÷ 0.056
8. Sept.	2P50	744	0.0385	271.8	0.262	+ 0.028	÷ 0.068
11. —	10A00	738	0.0271	269.0	0.186	÷ 0.048	÷ 0.126
12. —	9A30	738	0.0307	270.7	0.209	÷ 0.025	÷ 0.040
15. —	3P20	745	0.0343	266.1	0.244	+ 0.010	÷ 0.090
17. —	2P50	742	0.0253	268.4	0.176	÷ 0.058	÷ 0.044
10. Oct.	1P50	737	0.0283	259.9	0.208	÷ 0.026	+ 0.035
21. —	1P30	755.5	0.0373	257.8	0.28_6	+ 0.052	+ 0.148
				Mean...	0.234		÷ 0.003

By putting $k_m^{IX} \div 0.003 = 0.234$ one may, on the strength of this, get the mean value of the co-efficient of refraction for the sight Observatory—Cairn IX for the period May 31st—October 21st. It is:

$$k_m^{IX} = 0.237$$

where the second decimal may be supposed to be reliable. The great difference between the values of $\Delta\varkappa$ and Δk is a fact for which, as mentioned above, one must be prepared. It is a striking fact that whereas $\Delta\varkappa$ oscillates between $+ 0.059$ and $\div 0.058$ Δk oscillates between $+ 0.176$ and $\div 0.126$. Similar conditions though not quite so marked we shall find at the lines of vision at Cairn X and at the „Skerry". The cause of this we will treat later on.

In the table given below (p. 173) of refraction conditions in the line of vision Observatory—Cairn X no mention is made of the conditions on September 11th, because, on that day, the kite only reached an altitude of 200 m. As k_m^X is determined at 0.160 I have not formed the values $\Delta\varkappa$ and have, instead of Δk, given k as determined by $k = 0.160 + \Delta k$. At the computation of the means it has been necessary, on account of the too abnormal conditions, to leave out the figures given in brackets for October 21st. In order to show the justice of not including the values of that day in the means, I shall quote — from WEGENER's above-mentioned "Drachen- und Fesselballonaufstiege" — the result of the ascension of kites on that day.

With the colossal inversion of 10.9 to 11.2 degrees between 200 m and 500 m (at 1P18 to 1P48; see below) it is quite natural that we must get an abnormally high value of $\varkappa_X$, and to this should correspond a similar abnormally high value of k. On this day we also get the highest

value of k corresponding to the sight at Cairn X, that is $k = k_m^X + 0.199 = 0.359$ (see table p. 156); but this value we get during the observation at 8^a50, whereas the observation at 1^p30, for which $\varkappa$ is computed, makes $k = k_m^X + 0.086 = 0.246$. The vertical movement for Cairn X was at 8^a50 as well as at 1^p30 estimated at 3, and was, as mentioned on p. 169, at 1^p30 measured at 15″.5, to which corresponds $dk = 0.128$. It is only reasonable, that under conditions of this kind and especially in reference to the sharp breaks in the direction and velocity of the wind (as to this see later) one can only get quite abnormal differences between k and $\varkappa$, and this seems to have occurred on October 21st. As there are now only nine simultaneous values of k and $\varkappa$ at Cairn X, an abnormal case will have quite a disturbing effect on the means.

21. October. 1 Drachen (4 m²), 1900 m Draht.

Zeit	Seehöhe m	Luftdruck mm	Temperatur C°	Rel. Feuchtigkeit %	Wind m. p. s.
1^p00	5	763 9	÷ 15.0	77	WNW 8
1 18	200	745	÷ 12 6	76	W 8
1 25	500	716	÷ 1.7	62	WSW 12
1 38	930	679	÷ 1.7	49	WSW 9
1 48	500	...	÷ 1.4	47	WSW 12
1 55	200	...	[1]	..	W 8
2 15	5	...	÷ 15.1	77	WNW 11

[1]) Wegen zu schneller Änderung unbrauchbar.

„Bewölkerung 3—2° a-str., zuletzt auch Föhnwolken. Starke Luftspiegelung nach oben an der grossen Koldewey-Insel. Höchste Temperatur im Aufstieg bei 600 m ÷ 0.8°, im Abstieg ÷ 0,3° bei 700 m. Blätterige Temperaturschichtung, der Windschichtung entsprechend: Bis 180 m WNW 4—8 m. p. s., noch fast keine Temperaturzunahme. Darüber bis 300 m W 8 m. p. s., Temperatur steigt um c. 5°. Hier weiter scharfer Temperatursprung um mehr als 5°, und Sprung des Windes auf WSW 12 m. p. s.

Ascensions of kites and balloons took place in the immediate neighbourhood of the coast. The values of τ and T required for the computation of $\varkappa$ may therefore be supposed to correspond very well to the conditions of the line of vision at Cairn IX, which is quite short and extends along the coast, whereas one must be more doubtful as to their practicability at the computation of the refraction conditions in the line of vision at Cairn X.

The effect of considerable areas of water is that the co-efficient of refraction of the air above them has a greater value than across land. This condition in particular makes itself very much felt in Northeast Greenland, as is clearly indicated by the values $k_m^X = 0.160$ and $k_m^S = 0.516$. From the following it will appear, that as far as

The refraction conditions in the line of vision Observatory—Cairn X.

Date	Hour	b_X	$\tau_X+0.0342$	T_X	$\varkappa$	k	Vertical movement on X
12. August ..	8P30	735.5	0.0389	278.7	0.249	0.241	not observed
27. — ..	8P00	743	0.0365	274.9	0.242	0.216	not observed
31. — ..	11a00	744 5	0.0326	272 4	0.221	0.118	1
8. Sept.	2P50	732	0.0314	271.6	0.210	0.090	1
12. —	9a30	727	0.0302	270.6	0.202	0.094	0
15. —	3P20	733.5	0.0329	266.0	0.230	0.100	1
17. —	2P50	730.5	0.0263	267.6	0.181	0.088	1
10. October..	1P50	725	0.0336	259.8	0.243	0.158	0—1
21. — ..	1P30	744	0.0610	262.8	(0.443)	(0.246)	3
				Mean..	0.222	0.138	

the line of vision to the "Skerry" is concerned, $\varkappa$ is computed with comparative certainty at 0.520, whereas for the line of vision at Cairn IX we found $\varkappa = 0.234$ with rather less certainty. In the first case we have a line of vision, nearly exclusively traversing water at a mean altitude of 15 m; in the second case the line of vision exclusively traverses land, but along the coast, at a mean altitude of 97 m. This change in the position and altitude of the line of vision causes a change of $\varkappa$ to the extent of about 0.29! After this one must suppose that to the line of vision at Cairn X, which traverses land and the mean altitude of which is 222 m, must correspond a k_m^X, which is considerably smaller than k_m^{XI}, and consequently also, that the value of $\varkappa = 0.222$ computed above, and corresponding to the line of vision at Cairn X is too great.

It might seem that the difference $0.222 \div 0.138 = 0.084$ (see table above) under these conditions is not very marked. It must, however, be remarked that k_m^X being determined at 0.160 the $\varkappa$ corresponding to this value should be about $0.222 + (0.160 \div 0.138) =$ about 0.242, whereas for the line of vision at Cairn IX by a similar consideration we should get the value of 0.237. It would be absurd to suppose that the co-efficient of refraction for the line of vision at Cairn IX should not be greater than for the line of vision at Cairn X. The consideration shows that the material for a comparison between $\varkappa$ and k is not sufficiently comprehensive, as has already been stated several times.

That which in the first place aroused my interest in a computation of the values $\varkappa$ was the idea of controlling, in this manner the values of k_m^X and k_m^S resting on the few reciprocal, simultaneous zenith distance observations, thus in this case of the value $k_m^X = 0.160$.

The absurdity demonstrated is, however, practically independent of the value 0.160 in that the difference $0.160 \div 0.138 = k_m^{\text{X}} \div \left(k_m^{\text{X}} + \frac{\Sigma \Delta k}{8}\right) = \div \frac{\Sigma \Delta k}{8}$. Therefore there is every likelihood that the eight values of Δk used in the table p. 173 are unfortunately placed for the comparison with the corresponding values of $\varkappa$ and that the value $\frac{\Sigma k}{8} = 0.138$ ought to have been greater or $\frac{\Sigma(\varkappa \div k)}{8} < 0.084$.

For the computation of $\varkappa$ corresponding to the line of vision to the "Skerry" τ and T are determined from observations of the temperature at the level of the sea and in the crow's nest[1]) made simultaneously or nearly simultaneously with the levellings. As the observations of temperature are made at a distance of about 85 m from land, and as the altitude of the crow's nest is only 30 m, the values determined for $\tau = (t_{30} \div t_0) : 30$ and $T = 273 + {}^1/_2 (t_{30} + t_0)$ may be supposed to correspond fairly well with the conditions above the fjord, at an altitude of 15 m. It will be borne in mind that the line of vision throughout its extent lies between the altitude 13.9 m and 16.4 m.

There are in all nineteen levellings with simultaneous observations of temperature. As far as the computation of the mean was concerned, it proved necessary to leave out the values of June 15th at 10P10. In the case of k it is, as in the case of Cairn X, the abnormally high maximum value ($k^{\text{S}} = 1.719$) which is left out.

The observations of temperature for the evening in question are as follows:

	8P	10P	Midnight
In the crow's nest ...	+ 3.0	+ 2.1	+ 1.4
On the ice	÷ 1.0	÷ 0.4	÷ 2.6
Δt	+ 4.0	+ 2.5	+ 4.0
τ	+ 0.133	+ 0.083	+ 0.133

The levelling at the "Skerry" is made very nearly at 10P15, probably a little later than the observation of temperature given for 10P. To the value $k = 1.719$ would correspond $\tau =$ about $+ 0.253$ or $\Delta t =$ about $+ 7.5$ degrees — an uncommonly large inversion, which would however not have been obvious. Still the inversion in the harbour is measured at + 2.5, whereas at 8P and at midnight it is + 4.0. In the journal of the levellings "strong glimmer" is recorded for the "Skerry" as well as a strong downward mirage, in other words conditions which seem to indicate disturbances in the conditions of refraction and great changes of

[1]) See W. Brand: Die Temperatur in der Ausguckstonne am Grossmast der "Danmark"; Medd. om Grønland, XLII.

temperature in the lowest strata of air. Under these circumstances I thought that the means would express more correctly the actual state of affairs, if I left out the values of June 15th 1908 at 10P10 from the computations. These values are given within brackets in the table below.

Refraction conditions in the line of vision: the Observatory—the "Skerry".

Date	Hour	b_S	$\tau_S + 0.0342$	T_S	z	k
23. Aug. 07	2P30	757	0.0775	273.6	0.529	0.296
— —	8P30	758	0.0542	271.9	0.372	0.466
24. —	3a15	759	0.0642	271.7	0.445	0.583
— —	10a40	759	0.0675	272.3	0.466	0.449
13. Sept. 07	7P00	756	0.0475	269.6	0.338	0.324
14. —	5a40	758	0.0442	268.2	0.314	0.243
— —	7a10	758	0.0375	268.0	0.267	0.304
— —	11a10	758	0.0409	269.1	0.289	0.254
— —	3P10	758	0.0475	269.8	0.334	0.275
— —	7P20	757	0.0542	266.4	0.390	0.364
21. Oct. 07	8a50	763	0.0542	252.7	0.437	0.344
— —	1P30	760	0.0442	258.0	0.341	0.332
15. June 08	2P10	756	0.0675	275.2	0.454	0.448
— —	6P10	756	0.0942	275.3	0.634	0.577
— —	10P10	756	0.1175	273.8	(0.795)	(1.719)
16. —	2a00	756	0.0609	274.0	0.414	0.780
— —	6a10	756	0.1542	273.2	1.054	1.221
— —	10a30	756	0.1375	274.6	0.930	0.641
— —	2P00	755	0.0509	273.6	0.346	0.475
				Mean..	0.520	0.524

The agreement between the means of z and k is, no doubt, to a certain degree an accidental one, but still points to the correctness of the value of k as determined by the reciprocal simultaneous zenith distances, so that $k_m^S = 0.516$ may be considered as expressing in a reliable manner the co-efficient of refraction in the line of vision; the Observatory—the "Skerry". In this manner the value determined for the line of vision: the Observatory—the Horizon II i. e. $k_m^{II} = 0.584$ also gains in certainty.

A glance at the three tables of simultaneous values of z and k not only shows a very marked disagreement between the single values, but also shows that k varies very much more than z. For the values given in the tables which have been used for the computation of the means, we get

	$\varkappa$			k		
	Max.	Min.	Diff.	Max.	Min.	Diff.
Cairn X	0.249	0.181	0.068	0.241	0.090	0.151
Cairn IX	0.293	0.176	0.117	0.413	0.111	0.302
"Skerry"	1.054	0.267	0.787	1.221	0.243	0.978

This points to two facts:

1) that the co-efficient of refraction varies much more in the case of low-lying lines of vision between points with a small difference of altitude than in the case of lines of vision between points, the difference of altitude of which is proportionately great, and
2) that in the determination of k circumstances make themselves felt, which do not, or at any rate not in such a high degree, influence the determination of $\varkappa$.

The cause of both of these circumstances is to be looked for in the stratification of the atmosphere.

$\varkappa$ is, as demonstrated, first and foremost dependent upon τ. In "Meteorologische Terminbeobachtungen am Danmarks Havn", Medd. om Grønland XLII, p. 318, Wegener has made public a thermogram which shows how strongly and with what extreme suddenness the temperature may oscillate. These sudden oscillations of temperature of several degrees may suggest the existence of a stratification with a great jump in temperature at very nearly the same altitude as that of the thermograph. The wave movement which must be supposed to take place in the strata causes the thermograph to be alternately in the colder or warmer stratum.

In the case of the line of vision at the „Skerry", the altitude of which only varies between 14 and 16 m it is, under these circumstances, easily understood that τ and so also the co-efficient of refraction — both $\varkappa$ and k — must vary greatly. In the case of the lines of vision at Cairn IX and Cairn X a wave movement of this kind in the stratification cannot in the same degree influence τ which is, it must be borne in mind, a mean value of the whole stratum of air between the Observatory and the cairn. In case the boundary between the strata is situated in such a manner that its waves do not touch any of the extreme points of the line of vision, it excercises no influence whatsoever neither on τ nor — consequently — on $\varkappa$.

In the case of the lines of vision at the „Skerry" τ was deter-

mined, not by measuring the difference of temperature at an altitude of 14 and 16 m but by measuring the temperature in the altitude of 0 and 30 m. If now in certain cases a sudden jump of temperature has taken place in the very altitude of the line of vision, τ has been incorrectly determined, and the effect of this must be that the values of k varied more than the corresponding computed values of $\varkappa$. In the case of the lines of vision at the cairns IX and X this view can hardly be upheld; it may therefore be supposed, at least as far as these lines of vision are concerned, that the chief reason of the difference between $\varkappa$ and k is not to be sought in the uncertainty of the determination of τ.

The presuppositions on which the computation of k is based is not only that the level surfaces within the distances in question may be looked upon as concentric spherical surfaces, but also that the density of the air in the case of each of these surfaces in everywhere the same. In other words, the atmospherical stratification should form concentric spherical surfaces coincident with the level surfaces. This presupposition, which roughly speaking may be supposed to be permissible, hardly holds good in the single cases.

A boundary between atmospheric strata may sometimes become visible. This is the simple consequence of a considerable inversion of temperature, in that the aqueous vapour condenses in the colder, lower-lying stratum; the upper side of the cloud thus coincides with the boundary. During later years a great many photographs of upper surfaces of clouds have been taken during balloon-trips, which photographs generally show a similar wave movement to the one to be found in water, only of much greater dimensions.

The wave movement is often expressed in the form of the clouds, as seen from the surface of the earth, and in this manner it has become possible to measure the length of the waves, which seems to be able to exceed 2000 m. In the lower strata of the atmosphere the length of the waves is, however, smaller than in the higher strata: for the lowest two kilometres one has, as a mean value of the length of the waves, arrived at 200 m[1]). A special form of wave movement may occur where the wind meets an obstacle, as for instance a mountain range or the top of a mountain. The stratification may then bend upwards over the obstacle and resume its normal course on the opposite side, and thus it forms a standing wave over the obstacle, which fact is found everywhere in mountainous regions, but it is particularly well known in Greenland and causes the formation of the mushroom-shaped Föhn-clouds. (The cloud

[1]) Alfred Wegener: Thermodynamik der Atmosphäre, Leipzig 1911.

apparantly rides on the top of the mountain, in which manner the wave becomes visible.)

In the wave movement it is to be supposed that the chief reason of the above-mentioned vertical movement of the objects is to be sought, and so we also get an explanation why k oscillates more than $\varkappa$ which is, in many cases, not influenced by the waving movements of the stratification.

The variation of the co-efficient of refraction according to the season.

The two tables on pp. 156—157 and p. 162 of the levellings undertaken, are divided into three sections corresponding to the periods May 31st to June 22nd, July 9th to August 12th and August 23rd to October 21st. This division corresponds fairly well with three seasons, each with its own climatic peculiarities: the period of the melting of the snow, midsummer and autumn. It is therefore to be expected, as will by the way appear directly from the tables, that the conditions of refraction within each of these periods must show a definite tendency.

In the summary below I have given the mean value of the co-efficient of refraction for each of the three periods. Besides I have in the case of the lines of vision at the cairns IX and X given the mean value of τ (the rise of temperature per metre) for the intervals 5 m to 200 m and 5 m to 500 m. These mean values of τ are computed from the results of all the kite- and balloon-ascensions within the period in question. The number of single values, on the strength of which the mean value of τ has become determined, is given in a special column. In the case of the line of vision at the "Skerry" I have not made a similar computation of τ. The reason of this is that the observations of temperature on the ice and in the crow's nest were only undertaken one day and night in the course of every month, during which day and night observations were made every second hour. It is therefore possible that the conditions on the day and night in question may have been abnormal, so that a comparison between τ and k might be quite misleading. However a cursory examination shows that this would hardly have been the case.[1]).

It appears that there is a certain harmony between the manner,

[1]) See: Die Temperatur in der Ausguckstonne am Grossmast der "Danmark" von W. Brand, Medd. om Grønland XLII. As to the series of observations July 17—18 1907 the mean value of the inversion has by a misprint been given as $\div 1.1°$ C.; it should be $+ 1.1°$.

	Cairn X: $k_m^X = 0.160$			Cairn IX: $k_m^{IX} = 0.237$			Cairn V	Skerry $k_m^S = 0.516$	Horizon II $k_m^{II} = 0.584$
	k	τ	Number of determin. of τ	k	τ	Number of determin. of τ	k	k	k
May 31st—June 22nd	$k_m^X \div 0.030$	$+0.0011$	24	$k_m^{XI} \div 0.037$	$+0.0002$	21	$k_m^V + 0.038$	$k_m^S + 0.156$	$k_m^{II} + 0.186$
July 9th—Aug. 12th .	$k_m^X + 0.030$	$+0.0062$	29	$k_m^{IX} + 0.034$	$+0.0014$	21	$k_m^V \div 0.072$	$k_m^S + 0.178$	$k_m^{II} + 0.359$
Aug. 23rd—Oct. 21st .	$k_m^X \div 0.004$	$+0.0014$	34	$k_m^{IX} \div 0.001$	$+0.0004$	28	$k_m^V \div 0.059$	$k_m^S \div 0.175$	$k_m^{II} \div 0.203$

in which k and τ vary. The necessary data for the computation of z corresponding to the given values of τ are to be found in Medd. om Grønland XLII. In this case one can, however, not expect agreement between k and z, because the mean values given are based on a comparatively small number of single determinations of k and τ, which furthermore generally occur on different days.

The summary shows that the refraction, as was to be expected, varies somewhat differently in the case of lines of vision across land (IX and X) than in the case of lines of vision across water (V, the "Skerry", Horizon II). However it is common to all of the five lines of vision that the co-efficient of refraction is greatest during the real summer season. This is the opposite of what is known from the other places, where the co-efficient of refraction is greatest during the winter. An explanation is consequently needed.

First of all it must be remarked that as observations of the refraction at Danmarks Havn during the months of winter and spring are lacking altogether, it is a question whether the co-efficient of refraction has not also a maximum during the winter or spring. This is undoubtedly the case. Fig. 14, which is reproduced from the often mentioned work of WEGENER: "Drachen- und Fesselballonaufstiege" shows the yearly rate of the difference of temperature between 5 m and 200 m altitude. The curve may be directly looked upon as representing the yearly rate of $\tau = \frac{dT}{dh}$ in the interval in question. The curve shows that corresponding to the coldest time of the year there is a maximum of τ (in consequence of the strong irradiation during the winter), and we must suppose that to this corresponds a maximum of k. Whether this

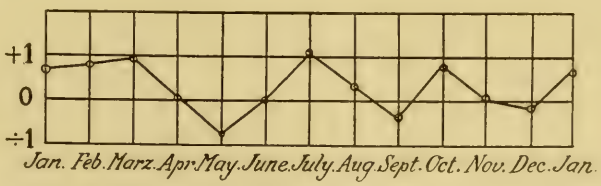


Fig. 14. Yearly rate of the difference in the temperatures at 5 m and 200 m above the sea.

maximum is greater than the midsummer one must remain an open question, though I must remark that the summer maximum shown in Fig. 14 is probably too small, as will appear from what is given below.

In his explanation of the summer maximum Wegener starts from the consideration that the lowest stratum in the air, the temperature of which, in July and the first two thirds of August, is practically always above zero, should give heat to the melting process going on during the whole of the summer. In this connection he refers to the fact that through the whole of the summer there are on the so-called snow-bare land here and there drifts of snow, that there is a greater névé on Germania Land, and in particular that the snow- and ice-bare area of land is very inconsiderable compared to the vast areas, which are covered by the adjacent inland ice and the still nearer sea ice.

I cannot altogether follow Wegener in this line of reasoning. The areas on Germania Land covered with perennial snow-drifts and névés are too inconsiderable to have any noticeable influence as to the atmospherical temperature of the summer. One might even be tempted to suppose that as the snow-bare land and the water in small lakes, watercourses and boggy tracts by means of the insolation would be heated considerably above the temperature of the air[1]), the lowest stratum of air which sweeps along the surface of the earth must receive some heat from the latter. The nearness of the inland ice hardly plays any part in relation to the summer temperature at the surface of the earth; at least there is nothing which seems to suggest, that the summer should be colder nearer the ice border than along the coast. On the contrary. The coast sea which is full of floating ice is, on the other hand, of very great importance to the summer temperature near Danmarks Havn.

In "Meteorologische Terminbeobachtungen am Danmarks Havn" Wegener gives a summary of the frequency calculated in percentage with which the various directions of the wind occur in the single months near Danmarks Havn. From Wegener's summary I have made the table given below, where under the column "land wind", that is wind which comes to Danmarks Havn from land, I have collected the directions N, NW and W, whereas the column "sea wind" comprises the directions S, SE, E and NE. Wind from SW, which comes to Danmarks Havn from Dove Bugt, does not show the marked characteristics of the sea wind, and is probably

[1]) See: Andr. Lundager: Some notes concerning the Vegetation of Germania Land, Medd. om Grønl. XLIII.

of no importance to the proportion between the frequency of the land wind and the sea wind.

In the table I have therefore placed SW next to calm.

Directions of wind occurring at Danmarks Havn, calculated in percentage.

	Land wind	Sea wind	SW	Calm or nearly calm
January	64 %	6 %	2 %	28 %
February	67	4	1	28
March	63	10	2	25
April	48	15	3	34
May	33	36	4	27
June	35	42	3	20
July	30	53	2	15
August	33	33	10	24
September	66	16	6	12
October	65	6	0	29
November	61	6	3	30
December	48	14	1	37

The table shows that it is only during the months May to August that the winds from the sea come to exercise a greater influence on the meteorological elements at Danmarks Havn. The element which in this case is interesting beyond all others is the temperature. If we go over the tables of the three daily regular observations, in "Meteorologische Terminbeobachtungen am Danmarks Havn", Medd. om Grønl. XLII, we are able to deduce the following:

April: No noticeable difference between the temperature of the sea wind and the land wind.
May: The sea wind nearly one degree colder than the land wind.
June: The sea wind nearly one degree colder than the land wind.
July: The sea wind nearly three degrees colder than the land wind.
August: The sea wind nearly two degrees colder than the land wind.
September: No noticeable difference between the temperature of the sea wind and the land wind.

Characteristic of the sea wind is, besides a high percentage of moisture, a small wind velocity and a large decrease in the velocity of the wind according to the height. The consequence of this is that the sea wind generally only reaches a very small altitude, after which, through a zone of calm or with a bound, it becomes a land wind or south-westerly wind, which in these cases has common characteristics with the land wind. The kite-ascensions, very few in number,

which it has been possible to undertake with the light sea wind, teach us nothing of the conditions of temperature above the sea wind, because with the primitive means at our disposal, it was not possible to "throw" the kites into the nearest higher stratum of the air. On the other hand, there are within the period June 9th—September 9th eight balloon-ascensions, of which the seven show a considerable rise in temperature at the transition from sea wind to land wind (SW) or calm.

The altitude in which this sudden change of temperature occurs varies greatly; in the course of the seven kite-ascensions it lay in two cases between 5 m and 200 m, in four between 200 m and 500 m, and in one between 500 m and 1000 m. It is however very probable, that the sudden change in temperature at the transition from sea wind to land wind or calm often lies below 200 m. I base this opinion on the fact that the column "Calm or nearly Calm" in the above table includes a number of cases, where there was a very light sea wind, which in the journal was recorded as calm[1]). The altitude of this very light sea wind must be supposed to have been very slight, often undoubtedly under 200 m.

It will now appear why the summer-maximum showed in Fig. 14 must be supposed to be too small. As far as the kite-ascensions are concerned it either refers to a land wind or an exceptionally strong sea wind, in which latter case the great inversion — in so far as it has existed — has been exceptionally high. As far as July is concerned — the month for which the frequency of the sea wind is 53 %, and for which the temperature of the sea wind is on an average three degrees lower than that of the land wind — there are, in the case of both years, only four balloon-ascensions with an easterly wind of in all seventeen kite- and balloon-ascensions during the same month. It is therefore a reasonable supposition, that the special circumstances connected with the effects of the sea wind on the inversion and so also the co-efficient of refraction, has not been fully expressed in the maximum shown in Fig. 14.

In the reflections here set forth lies the chief cause of the maximum, which the co-efficients of refraction, corresponding to the lines of vision at the cairns IX and X, show during the period July 9th to August 12th. This maximum must thus be looked upon as a phenomenon connected with the coast, and not as something which one might generally expect to find during the summer in high-arctic regions.

The corresponding maximum to Cairn V, the "Skerry" and

[1]) See: "Meteorol. Terminbeob.", Medd. om Grønland XLII, p. 326.

Horizon II are due to a different cause. It owes its existence to the inversion, which must necessarily occur during the warm season, when the air passes closely over the relatively cold water (ice). The rise of temperature must necessarily be strongest immediately above the water, which also appears from the three values given for the period July 9th—August 12th: $k_m^{\mathrm{V}} + 0.072$ (mean altitude of the line of vision 52 m), $k_m^{\mathrm{S}} + 0.178$ (mean altitude of the line of vision 15 m) and $k_m^{\mathrm{II}} + 0.359$ (mean altitude of the line of vision 7 m).

During the period May 31st—June 22nd the co-efficient of refraction appears very differently over land and over water (ice). The rather high value of the low lying lines of vision above water are due to similar causes as during the period July 9th to August 12th. As the atmospheric temperature in June is nearly three degrees lower than in July, though still positive, the inversion immediately above the ice becomes considerably smaller than in July. In the case of the lines of vision to the cairns IX and X one would expect a lower value of the co-efficient of refraction, partly because the sea wind is less frequent, and partly because it is only about one degree colder than the land wind. The month of June, however, shows such a low co-efficient of refraction over land that it might be reasonable to suppose the existence of a different cause. This is also the case.

Fig. 14 shows that the difference of temperature between 5 m and 200 m has a marked minimum in May. The reason of this is that the surface of the earth which had become considerably cooled in the winter, is warmed very quickly during the spring and early summer, on account of the radiant heat of the sun[1]). The heating of the air therefore cannot keep time with that of the earth, but lags behind. The relatively hot surface of the earth comes to exercise a heating influence on the lower strata of air. The reflexion from the snow, which during the month of May covers the greater part of the land, presumably plays no inconsiderable part in this process. The effect is that during the month of May, instead of a rise in

[1]) According to BRAND: "Die Temp. in der Ausguckstonne & c." the actinometric difference (the difference between the atmospheric temperature and the black bulk temperature) should be greatest in June, which harmonizes with the fact that the sun stands highest during this month. It must however be borne in mind that the series of observations for the determinations of the actinometric difference was only made for one day in every month, and as far as possible on days which might be expected to be free of mist. However, the weather journal for 1907 shows that the month of May, out of ninety-three observations, only has eight with mist and nimbus, whereas June out of ninety observations has thirty-four with mist and nimbus. The mean value of the actinometric difference must therefore be supposed to be considerabiy greater in May than in June.

temperature in the lowest 200 m, we get a fall in temperature which is, however, smaller than the normal — adiabatic — fall of temperature.

As far as the month of May is concerned, there are no determinations of the co-efficient of refraction, but judging from the above it is to be supposed that the value during this month is very low. June stands as the transition between the minimum of the month of May and the maximum of the month of July.

In contradistinction to the maximum of July—August, which turned out to be particularly connected with the coasts, the minimum of the early summer must, from what has been stated, be supposed to be found everywhere over land in high-arctic regions.

As far as the period August 23rd—October 21st is concerned, the lines of vision over land show mean values of the co-efficient of refraction, whereas the lines of vision over water show markedly low values.

The cause of the fall from the maximum of the summer is to a certain extent common to all lines of vision, that is the cold which begins to make itself felt towards the end of August, and which makes the water freeze. In this manner a considerable amount of heat is discharged, which preferably serves to heat the very lowest strata in the air, and there occasions a strong fall in temperature in an upward direction. This state of affairs, as was to be expected, in particular makes itself felt in the three lines of vision above water with mean altitudes of 52 m, 15 m and 7 m respectively, in that the co-efficients of refraction here assume the values: $k_m^{\mathrm{V}} \div 0.059$, $k_m^{\mathrm{S}} \div 0.175$, $k_m^{\mathrm{II}} \div 0.203$. In the case of lines of vision across land, the freezing of the water cannot come to play such an important part, partly because the areas of water and those of snow filled with water are comparatively small, and partly because the lines of vision here lie higher. As far as the lines of vision over land are concerned, another circumstance has to be taken into consideration, that is the fact that the temperature of the sea winds in September is not noticeably different from that of the land winds, whereby the special inversion, brought about by the sea wind, disappears.

The variation of the co-efficient of refraction according to the time of day.

In the preface to these remarks I have accounted for the casual character of the observations. The lack of system in the arrangement makes itself very much felt here where the object is to determine the influence of the time of day on the co-efficient of refraction.

It might seem a very likely a priori supposition that the influence of the time of day on the co-efficient of refraction must be very small in high arctic regions, particularly during summer and winter, because the day period in the temperature practically disappears at these times, and only plays any part at all during the spring and autumn. In the case in question it would consequently have been natural to undertake researches of the variation of the co-efficient of refraction for two periods, according as the sun is circumpolar or not, but our material does not permit of such a manner of proceeding, because the single times of day and night in this manner would be covered by far too small a number of observations. I have therefore come to the conclusion that it would be most correct to treat the whole material in a lump. In order to eliminate the disturbing influence of the seasons as much as possible I have corrected all the single values of Δk for the special increase due to the season. As an example I shall mention that the first named value in the table below has been arrived at by taking the value of Δk on August 24th, at 3^a15 from the table on p. 156 and adding to this 0.004 (cf. the summary of the variation of the co-efficient of refraction according to the season, p. 179). The values of Δk given in the table below are expressed in units of the third decimal place.

In grouping the observations according to the time of day I have aimed at getting, within each group, such a large number of observations, that one might reasonably hope that the casual character of the material would not influence the means of the groups to such an extent as to be fatal to the sense. The unsystematic manner in which the observations have been undertaken, has quite naturally brought about the result that these observations group themselves more closely round certain hours within the twenty-four than round others. The intervals between the means of the single groups, therefore, become unequal; for instance it has not been possible to avoid a very large interval near midnight.

The levellings at the sea horizon were undertaken on the same days as the other levellings, but either before or after the latter. As it was of great importance to me that the groups formed in the case of Horizon II should come to contain single values of the same date as the corresponding groups for the other lines of vision, a seeming arbitrariness has been introduced at a few points; in that the value of May 31st at 11^a50 has been reckoned with the group before noon, whereas the value of October 9th 11^a50 has been reckoned with the group immediately after noon; in the same manner the observations made at 8^p40 on August 27th and September 11th have been given in two different groups.

The variation of the co-efficient of refraction according to the time of day.

Date	Hour	Temp.	X Δk ÷	X Δk +	IX Δk ÷	IX Δk +	V Δk ÷	V Δk +	Skerry Δk ÷	Skerry Δk +	Hour	Temp.	II Δk ÷	II Δk +
24. Aug. ...	3a15	÷ 2.6		55		261		175		242	4a20	÷ 2.6		242
28. — ...	5a40	÷ 2.2		39		36		9		39	6a20	÷ 2.2		51
14. Sept. ...	5a40	÷ 5.0		74		24		24	48		3a30	÷ 5.7		79
16. June ...	2a00	+ 1.4		23		84		4		108	2a20	+ 1.4		238
Mean .	4a.1		+ 48		+ 101		+ 53		+ 85		4a.1		+ 152	
9. Aug. ...	9a00	+ 3.5	26			132		82	364		9a50	+ 3.5	42	
12. Sept. ...	9a30	÷ 2.0	62		39		10		72		9a00	÷ 2.0	90	
14. — ...	7a10	÷ 4.6	1			76	24		37		7a40	÷ 4.6	142	
21. Oct. ...	8a40	÷ 20.4		203		186		10		3	9a30	÷ 20.3	195	
16. June ...	6a10	+ 1.6	40			51		83		549	6a30	+ 1.6		216
18. — ...	9a00	+ 2.4		6	59			9	16		9a20	+ 2.4	12	
Mean..	8a.2		+ 13		+ 58		+ 25		+ 10		8a.6		÷ 44	
23. July ...	10a50	+ 6.2		4	11			115		122				
27. — ...	9a45	+ 5.2		103		142		154		289				
28. — ...	11a00	+ 5.8	25		25			17		3	11a00	+ 5.8		12
24. Aug. ...	10a40	0.0	19			59		60		108	11a30	+ 0.2		15
31. — ...	11a00	÷ 0.3	38		55		35		24		10a40	÷ 0.8		58
11. Sept. ...	10a00	÷ 3.4	28		125		74		89		9a40	÷ 3.4	154	
14. — ...	11a10	÷ 3.0	97		175		79		87		11a30	÷ 3.0	204	
10. Oct. ...	9a40	÷ 14.6		27		1		8		28	10a00	÷ 12.6	110	
31. May ...	10a10	÷ 2.8		206		180	79		342		11a50	÷ 2.5	433	
16. June ...	10a30	+ 1.7	37			77	40		31		10a40	+ 1.7	95	
Mean..	10a.5		+ 10		+ 7		+ 5		÷ 2		10a.8		÷ 114	
2. Aug. ...	1p30	+ 6.5	18		128		84		149		2p10	+ 6.5		29
11. — ...	2p00	+ 8.8	10			41		94		181				
27. — ...	1p10	+ 3.0	57		62		41			97	0p20	+ 1.6		392
9. Oct. ...	0p40	÷ 10.2		42	4		31			13	11a50	÷ 10.0	7	
10. — ...	1p50	÷ 12.6		2		36	14		50		2p20	÷ 13.0	179	
21. — ...	1p30	÷ 15.5		90		149		31	9		2p00	÷ 16.0	166	
16. June ...	2p00	+ 2.5	35		26		15		197		2p20	+ 2.3	52	
22. — ...	1p20	+ 4.4		4	64		52		244		1p40	+ 4.4	4	
Mean..	1p.5		+ 2		÷ 7		÷ 14		÷ 45		1p.5		+ 2	
24. July ...	4p40	+ 2.1	24		69		171		394					
23. Aug. ...	2p30	+ 1.7	111		163		23		45		3p00	+ 1.7	78	
8. Sept. ...	2p50	÷ 1.6	66		39		36		55		3p30	+ 1.5		30
11. — ...	2p50	÷ 2.2	77		67			2	65					
14. — ...	3p10	÷ 2.7	66		76		38		66		3p30	÷ 2.7	138	
15. — ...	3p20	÷ 6.9	56		95		35		69		3p40	÷ 6.9	208	
17. — ...	2p50	÷ 3.8	68		43		52		41		3p20	÷ 2.9		26
15. June ...	2p10	+ 2.8	111		101		134		224		2p30	+ 2.8	114	
9. July ..	2p30	+ 11.2		60	137		113			64	2p50	+ 11.4	20	
Mean..	3p.0		÷ 58		÷ 88		÷ 67		÷ 99		3p.2		÷ 72	

Date	Hour	Temp.	X Δk		IX Δk		V Δk		Skerry Δk		Hour	Temp.	II Δk	
			÷	+	÷	+	÷	+	÷	+			÷	+
25. July ...	7P45	+ 8.2	8			165		19	22					
26. — ...	7P00	+ 5.8	101		78		106		273					
27. Aug. ...	8P00	+ 0.8		60		14		168		171	8P40	+ 0.8		457
13. Sept. ...	7P00	÷ 4.6		13	34		30		17		7P20	÷ 4.6		92
14. — ...	7P20	÷ 6.5		64		109		28		23	7P40	÷ 6.8		158
9. June ...	7P00	+ 0.8		16	120		131		326		7P20	+ 0.2	133	
15. — ...	6P10	+ 2.4	57		303		101		95		6P30	+ 2.4		77
20. — ...	0P50	+ 2.5		21	183			47	222		7P00	+ 4.4	141	
Mean..	7P.1		÷ 1		÷ 54		÷ 13		÷ 95		7P.4		+ 85	
27. July ...	11P00	+ 7.0		20	153			19		815	11P20	+ 7.0		119
29. — ...	10P00	+ 2.4	9		6		71		168		10P40	+ 2.4	164	
30. — ...	8P40	+ 7.1	4			29		125		368	9P10	+ 7.1		52
8. Aug. ...	10P10	+ 0.7	18		36		126		154					
12. — ...	8P30	+ 5.0		51		142		51	317		9P00	+ 3.5		15
23. — ...	8P30	÷ 0.9	5		39			64		125	9P10	+ 1.2		248
11. Sept. ...	8P20	÷ 4.3		95		31	61		78		8P40	÷ 4.3	191	
15. June ...	10P10	÷ 1.0		3		466		407		1047	10P30	÷ 1.1		449
Mean..	9P.4		+ 17		+ 54		+ 51		+ 205		9P.8		+ 75	

In order to facilitate the general view I have in Fig. 15 given a graphic sketch of the daily rate of the co-efficient of refraction, leaving out, however, the value of Horizon II, the grouping of which seems to have been particularly unsuccessful. It must be borne in mind that the abscissa line in Fig. 15 stands for the mean value of the co-efficient of refraction for each of the four lines of vision, in other words, a value which differs greatly in the case of each of the four lines.

The table and Fig. 15 show that the sudden and strong oscillations of the co-efficient of refraction make themselves felt in the mean values computed for the single groups, sometimes in a rather disturbing manner. In the figure this appears strongly, as far as the "Skerry" is concerned, in that the greatly deviating high value of 9P.4 is owing to the abnormal value of Δk on June 15th at 10P10. It appears particularly in the case of Horizon II, where the above-mentioned four values of 11a50 and 8P40, grouped with a somewhat doubtful justice, rather confuse the picture. If we had, in an arbitrary manner, interchanged the two values of 11a50 and so also the two values of 8P40, the daily rate of the co-efficient of refraction in the line of vision at Horizon II would have fitted in very well with the other values.

If it must thus be admitted that the material collected is not

sufficient to determine the daily rate, in a manner which is fairly accurate in all details, the figure, however, very clearly and with great certainty shows the main characteristics of this rate. These main characteristics — a pronounced minimum in the afternoon and a pronounced maximum during the night — which are common to the line of vision across land and across water, are in no particular different from what is known from other parts of the globe; in the case of the line of vision at Cairn X, I shall in particular draw attention to the characteristic feature that the co-efficient of refraction in the hours immediately before noon and as late as at 1P keeps fairly constant, which phenomenon is also well-known in Europe.

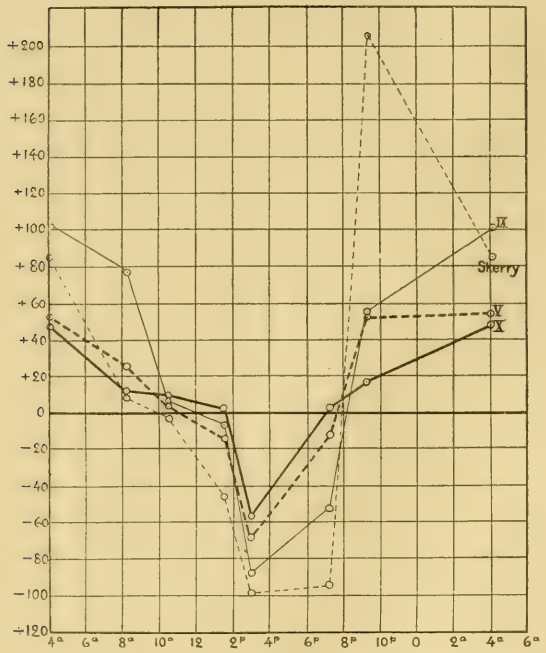


Fig. 15. Diagram of the daily rate of the co-efficient of refraction. The ordinates indicate the Δk's with the same value as given in the table above.

It has been proved, on an earlier occasion, that the curve of the variation of the co-efficient of refraction may, under a certain reservation, directly be looked upon as a curve of the variation of $\frac{dT}{dh}$ (the variation of temperature according to the altitude). On the Danmark-Ekspedition we did not succeed in proving, by means of a direct measurement of temperature, the existence of a daily rate in $\frac{dT}{dh}$, a consequence of the fragmentary nature of the measurements of temperature and disturbances by aperiodic changes[1]). Through the determination of the daily variation of the co-efficient of refraction a corresponding and simultaneous movement in $\frac{dT}{dh}$ may be considered as proved, as far as the lowest strata of the air are concerned.

The circumstance that the daily rate of the co-efficient of re-

[1]) See remark in Brand: Die Temperatur in der Ausguckstonne: Medd. om Grønl., XLII, p. 591.

fraction is in the main the same at Danmarks Havn as in other parts, seems to indicate that we are here dealing with quite a common factor of the co-efficient of refraction, the cause of which may thus be equally common. As such appear irradiation and radiation, which must be supposed to cause daily periodic oscillations of $\frac{dT}{dh}$. The actinometric difference may be considered as a measure of irradiation and radiation; it is therefore natural to seek a connection between the latter and $\frac{dT}{dh}$ or the co-efficient of refraction.

The mean values of the actinometric difference and the co-efficient of refraction within the period May—October:

Actinometric difference			Co-efficient of refraction	
Hour	a	Δa	Hour	$k = k_m + \Delta k$
8a	+ 14.1° C.	+ 3.8° C.	8a.2	k_m + 0.026
9a	+ 15.9	+ 5.6		
10a	+ 17.5	+ 7.2	10a.5	k_m + 0.005
11a	+ 19.1	+ 8.8		
12	+ 19.8	+ 9.5		
1p	+ 19.1	+ 8.8	1p.5	k_m ÷ 0.016
2p	+ 16.4	+ 6.1		
3p	+ 14.3	+ 4.0	3p.0	k_m ÷ 0.078
4p	+ 12.8	+ 2.5		
5p	+ 11.4	+ 1.1		
6p	+ 10.2	÷ 0.1		
7p	+ 8.1	÷ 2.2	7p.1	k_m ÷ 0.040
8p	+ 6.8	÷ 3.5		
9p	+ 6.3	÷ 4.0		
10p	+ 5.4	÷ 4.9	9p.3	k_m + 0.025
11p	+ 3.9	÷ 6.4		
0	+ 2.0	÷ 8.3		
1a	+ 1.9	÷ 8.4		
2a	+ 2.1	÷ 8.2		
3a	+ 3.4	÷ 6.9		
4a	+ 5.7	÷ 4.6	4a.1	k_m + 0.072
5a	+ 8.2	÷ 2.1		
6a	+ 10.2	÷ 0.1		
7a	+ 12 0	+ 1.7		
Mean..	+ 10.3			

On the Danmark-Ekspedition the actinometric difference was determined once in the course of every month by measuring every second hour through the twenty-four; the result of the measurings are given and treated in the frequently mentioned dissertation by Brand: "Die Temperatur in der Ausguckstonne". From the six series

of observations for the months May—October I have made a mean series. The observations in the single series are performed at hours corresponding to the full hours, but in the three cases at even hours, in the other three at odd hours. On account of the variations from month to month, this circumstance would cause the curve of the mean series to zig-zag from hour to hour. In order to avoid this picture, so fatal to the sense and corresponding in no wise to the actual conditions in nature, I have in every single series interpolated the value of the twelve hours on which no observations have taken place, and from the values obtained in this manner, from hour to hour, in the six series, I have made the mean series, the twenty-four single values of which are indicated above.

The significance of the irradiation and radiation in the case of $\frac{dT}{dh}$ is in all probability somewhat different over land and over water, as is also suggested by the curves shown in Fig. 15. In order that this may cause the smallest disturbance possible between the daily variation of the actinometric difference and the co-efficient of refraction, I have from the four curves in Fig. 15 made a mean curve, though at the computation of the ordinates from the table on pp. 186—187 I have left out the quite abnormal and disturbing values of June 15th at 10P10.

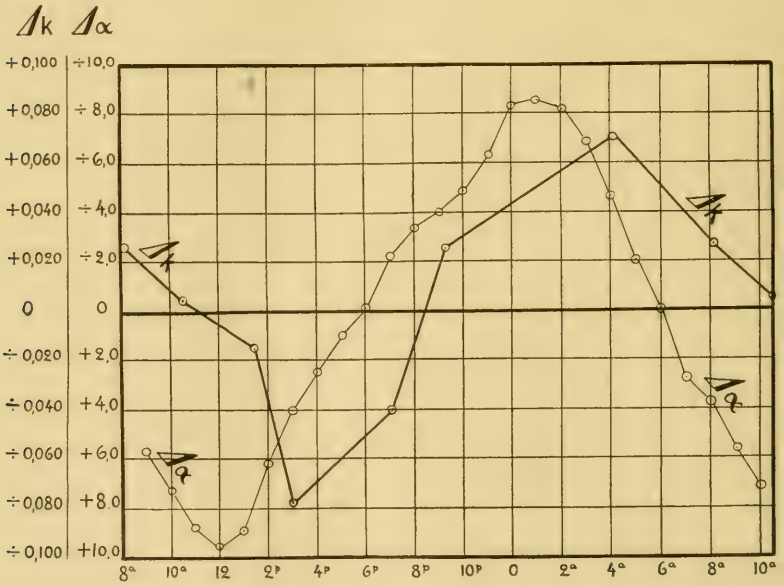


Fig. 16. The co-efficient of refraction and the actinometric difference.

In the table above the actinometrtc difference, α, is expressed in centigrade. In order to be able to use, in Fig. 16, for α the same

abscissa line as for k, the values $\Delta\alpha = \alpha \div \frac{\Sigma\alpha}{24}$ are formed, corresponding to the values Δk.

The connection between the actinometric difference and the co-efficient of refraction is not very obvious in the table, but nevertheless it appears extremely clearly in the diagram, in particular if, as in the curves given in Fig. 16 of values of $\Delta\alpha$ and Δk belonging together, the ordinates of the two curves are given opposite signs.

In spite of the paucity of the material, particularly as far as the co-efficient of refraction is concerned, Fig. 16 gives a very distinct hint as regards the connection between the actinometric difference and the co-efficient of refraction $\left(\frac{dT}{dh}\right)$ in that the figure gives us an incomplete picture of two curves of sine the phases of which show a difference of a couple of hours. A picture of this kind must indeed, seem a very plausible one.

An attempt to penetrate further into the problem here set forth would presumably, at the present moment, be quite futile, as the necessary material of observation is hardly to be found anywhere. A further development of the problem would therefore in far too high a degree be based upon closet reflections.

Special observations. Examples of anomalies of refraction.

When we commenced the observations at Danmarks Havn, with the object of determining the magnitude and variation of the co-efficient of refraction, we had not realized the close connection between the co-efficient of refraction and certain meteorological factors. However, we were rather quickly taught by experience that such a close connection existed, which led to the result, that wherever circumstances permitted, we levelled simultaneously with kite- or balloon-ascensions or with measurement of temperature in the crow's nest, In this manner it appeared that one might generally, with a cursory glance at the automatic diagrams from the kite- or the balloon-ascensions, form conclusions as to the tendency of the results of levelling, just as one might reversely from the levellings form certain conclusions as regards the existence and position of inversions &c. &c. By comparing the material already published, anyone may convince himself of this. A single very pronounced example is provided by the ascensions of kites and the levelling on October 21st 1907.

The journal of levelling for the observation series of 8^a50 shows the following result (instead of the readings I give Δz with the same value as in the tables on pp. 156—157 and p. 162).

21/X 1907, forenoon. Observer and assistant: Koch
Commenced at 8^a25,
finished at 9^a25.
Sunrise about 8^a45

Cover of clouds: 3° *a-str.*; wind: light easterly, after that calm.
$b_1 = 765.7\ (+\ 13.9)$[1]); $t_1 = \div\ 20.5$; moisture 77 %.
$b_2 = 764.6\ (+\ 12.2)$; $t_2 = \div\ 20.3$; moisture 78 %.
Glimmer[1]): 0, on the "Skerry" 0—1.
Mirage[1]): 0. On Store Koldewey upward mirage; seen from the ice and from the "Villa" downward mirage on the "Skerry".
Vertical movement: 3 on V, X and the "Skerry", 2 on IX.
In the crow's nest at 8^a45: $t = \div\ 20.0$; calm.
On the ice: $t = \div\ 20.6$.

In the first set a great rising of Store Koldewey, so that Cairn V had the country as a background[2]); in the second the country was again lowered so that Cairn V and the greater part of the knoll on which the cairn was situated, had the open air as its background. The difference between the altitude of the hinterland in set I and II was about $2^1/_2'$ to $3'$, measured at an estimate by the interval between the horizontal threads.

Δz.

X ..... $\div\ 24''.0$ (value extremely low).
IX ..... $\div\ 7''.9$ (value strikingly low).
V ..... $+\ 12''.4$ (value rather low according to the season).
The "Skerry".... $+\ 34''.1$ (normal value according to the season).
at 9^a30 Horizon II $+\ 144''$ (value strikingly high).

The levellings indicate a very low value of $\frac{dT}{dh}$ immediately above the sea ice. However, already in the line of vision at the "Skerry", $\frac{dT}{dh}$ is normal according to the season and thereafter increases very strongly up to the highest line of vision. The strong vertical movement in all objects indicates a marked stratification in the atmosphere.

The measurings of temperature on the ice and in the crow's nest show a rather normal rise in temperature in the lowest 30 m, which may tally with the normal zenith distance to the "Skerry". The low value of $\frac{dT}{dh}$ in the line of vision at the sea horizon is, in the case in question, controlled by means of the downward mirage, as seen from the "Villa". The height of vision at the last-mentioned

[1]) The temperature of the mercury. The two readings correspond to the beginning and cessation of the observations. Glimmer and mirage were recorded, like vertical movement, at an estimate in four intensities.

[2]) See Fig. 17 which corresponds to the condition during the observation at 1^p30.

place is 5 à 6 m above the sea. Below this height there must be a stratum of air with a great negative value of $\frac{dT}{dh}$. The upward mirage also shows great leaps of temperature in the higher strata $\left(\frac{dT}{dh}\right.$ positive$\left.\right)$ which tallies with the levellings at IX and X.

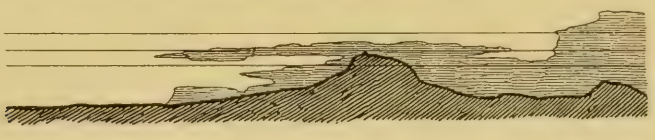


Fig. 17. Telescopic image during the levelling at Cairn V, Oct. 21st 1907 at 1P30. In the background upward mirage of Store Koldewey. The three horizontal lines are the horizontal threads of the telescope. Interval between middle thread and outer threads about 2′.

Under the above-mentioned, very striking conditions of refraction there was reason to expect interesting results of a kite-ascension; but on account of the calm weather no such ascension could be undertaken.

At noon the wind blew strongly from WNW, and the kite was

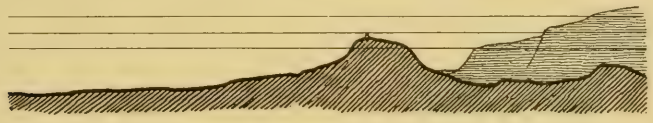


Fig. 18. Telescopic image during the levellings at Cairn V. Normal conditions of refraction.

sent up simultaneously with renewed levellings. The journal of these levellings shows the following result:

21/X 1907 afternoon. Observer: Koch; assistant: Friis
Commenced 1P15,
finished 1P50.
Cover of clouds: 2°—3°, *a-str.*, Föhn clouds.
Wind: WNW, 8 à 10 m.
$b_1 = 763.0$ $(+ 12.2)$; $t_1 = \div 15.0$; moisture 79 %.
$b_2 = 762.7$ $(+ 10.7)$; $t_2 = \div 16.0$; moisture 77 %.
Glimmer 1—2 everywhere.
Mirage 0; on Store Koldewey upward mirage (Fig. 17).
Vertical movement 2—3 at X, otherwise 0.

	Δz.
X (429 m)	$\div 10''.4$ (value strikingly low).
IX (180 m)	$\div 6''.3$ (value strikingly low).
V (90 m)	$+ 7''.0$ (value low according to the season).
The "Skerry" (16 m)	$+ 36''.4$ (value normal according to the season).
at 2P00 Horizon II.	$+ 137''$ (value strikingly high).

On pp. 171—172 I have mentioned that the vertical movement at X may have had a disturbing effect, and that Δz corresponding to X probably ought to have been considerably lower (cf. result of the observation at 8^a50); in the same place I have quoted the result of the kite-ascension. For comparison with the results of the levellings I shall here give the record of the temperature from the kite-ascension after Wegener's diagram in "Drachen- und Fesselballonaufstiege" p. 65. I draw attention to the peculiar angles in the curve between

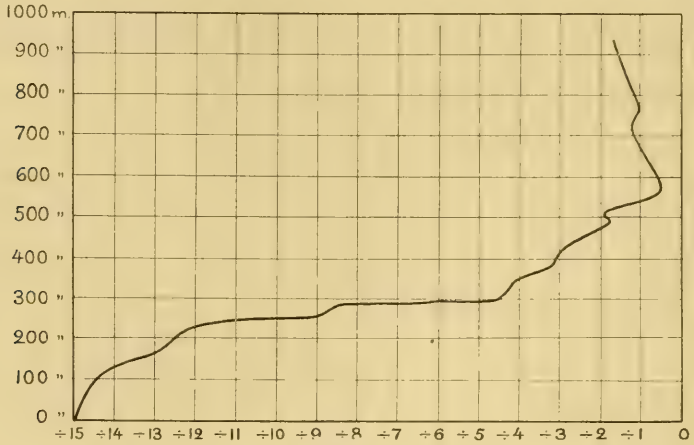


Fig. 19.

300 m and 600 m. The position of this "foliated" stratification one should perhaps connect with the circumstance that the vertical movement at this very Cairn X is estimated at an intensity of 2 à 3 whereas at the other objects it is zero.

The tension in the state of the atmosphere, which was clearly expressed in the levellings of October 21st, was broken through a rather inconsiderable Föhn, inaugurated during the ascension of the kite.

Fig. 20 shows a sample of the frequently occurring cases of an oblique sea horizon, caused by the nearness of the land. The interval between the horizontal threads is nearly 2′.

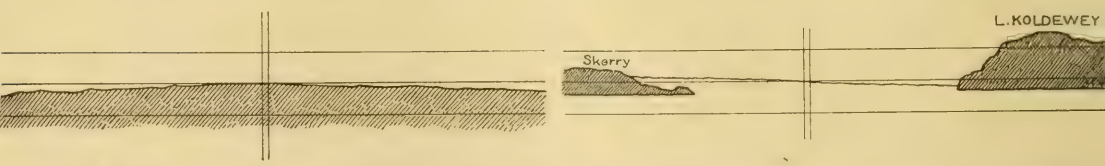


Fig. 22. Telescopic image of Horizon I (to the right) and Horizon II on September 11th at 2p20.

Fig. 21 gives an example of a curvature in Horizon III. The curvature, the greatest depression of which was measured at 12″, is

of the same kind as the outline of the country and must be supposed to be caused by the fact that the line of vision passes quite closely across the country.

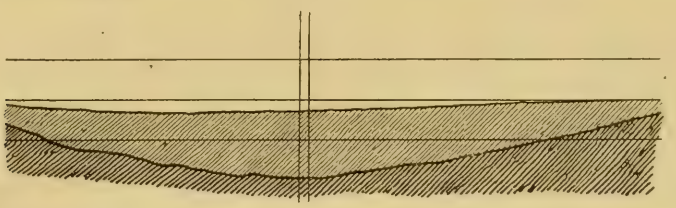


Fig. 21. Telescopic image of Horizon III, on October 21st at $9^{a}30$.

Fig. 22 shows a commonly occurring case of a false sea horizon, caused by a downward mirage over open water. Owing to the wave movement of the water the false horizon is rather uneven. The movement in the reflecting stratum of air has the effect that in the reflected image of the celestial vault under Horizon II one may catch a glimpse of the constant shifting of small wave crests, which seem to leap up from the false horizon, in order to subside immediately afterwards. The real horizon is just perceptible at solitary small floes in the water. At Horizon I, where a number of small icebergs

Fig. 20. Telescopic image of Horizon I (to the right) and Horizon II on August 12th at $9^{p}00$.

are gathered together, it was possible to point the real sea horizon. The difference between the zenith distance of the latter and the false horizon was here measured at 40″.

Fig. 23 shows a simultaneous downward and upward mirage[1]).

Fig. 23. Horizon II, double mirage on September 11th at $9^{a}40$.

The three small bits of calving ice clearly show the downward mirage. An observation of the zenith distances gave the following result:

[1]) The kind of upward mirage PERNTER (Meteorologisehe Optik), in the case of the sea horizon calls "Erhebung des Horizontes"; for the icebergs at the horizon he would presumably in this case use the designation "Verticalverzerrung".

Upper sea horizon	90°06′18″	Diff. 48″
Middle sea horizon	90°07′06″	
False sea horizon	90°07′55″	Diff. 40″

The difference between the boundaries of the mirages in the sea horizon was occasionally observed, as appears from the above-mentioned and from the table p. 162 of levellings at the horizon. When going over the weather journal in Medd. om Grönland XLII one gets an impression of the general occurrence of the phenomenon; here we likewise find a great number of diagrams and a few photographs of mirages. In chapter VI, "Features of the Geography of Northeast Greenland", the mirages are likewise mentioned and illustrated. A systematic investigation of mirages has not taken place on the expedition.

Concluding remarks.

As a practical geodetic problem the question of the terrestric refraction might be considered treshed out about the middle of the last century, in that it was recognized as impossible to surmount the practical difficulties, inseparable from trigonometrical levelling in consequence of the variation of the co-efficient of refraction, even though one might, by means of various measures, protect oneself against the worst drawbacks. The object of the treatment of the material of the Danmark-Ekspedition in this direction was thus a purely scientific one: By determining the co-efficient of refraction and the variation of the latter in various circumstances to attempt to deepen the understanding of certain peculiarities of the physics of the atmosphere.

In the course of the observations in Greenland and partly also by the treatment of the material, certain practical experiences have, however, been gained, the passing over of which in this place would presumably be wrong.

The great difference between the co-efficient of refraction over land and over water, combined with the strong and sudden oscillations of the co-efficient, encourages one to be still more distrustful of trigonometric levellings in Greenland — and in particular in Northeast Greenland — than in more southerly zones. Considerable disagreements between the results of the levellings are unavoidable. In chapter III I have given examples of how — in the course of geographical survey — to form an estimate of the reliability of the measuring of altitudes performed. Here I shall only add that the observation journal ought to contain particulars of observations, which may point towards special conditions of refraction, as in

particular the existence of mirages or Föhn clouds. Temperature, pressure of the air, velocity and direction of the wind, should be regularly recorded. During ascensions of mountains one ought in particular to direct one's attention towards changes in the velocity and direction of the wind according to the altitude; f. i. it very often happens in East Greenland, that there is calm or an easterly wind at the level of the sea, whereas at an altitude of a few hundred metres one may rather suddenly get a fresh westerly breeze and at the same time a higher temperature. Here one passes a stratification which may have a disturbing effect on the refraction in the lines of vision traversing it; consequently one ought to know approximately the corresponding altitude. Finally, at all the stations, from where the sea horizon is visible, one ought to level the latter at the commencement and conclusion of the observations. In so far as the altitude of the station is well defined, one gets through the latter a good basis for control, as to whether the value of the co-efficient of refraction used is fairly suited for sights at lower lying points. In case the altitude of the station is only verified in a defective manner, the levelling at the sea horizon may serve to control or according to the circumstances to correct the altitude of the station. (As to this see further chapt. III.

In the course of survey work performed in Greenland, one has often used the value $k = 0.2$, and generally there will hardly be any reason to choose a different value. In cases where low sights across water are the principal thing, there may, however, in North Greenland be occasion to use a considerably higher value, according to the circumstances as much as 0.6.

In practical navigation the knowledge of the angle of depression at the sea horizon plays a considerable part. The constant generally used for the computation of the angle of depression is badly adapted for the ice-filled part of the Greenland Sea. As we are here only dealing with low lines of vision, we may use the value $k = 0.584$. From

$$z \div 90° = \omega \sqrt{\frac{2\,(1 \div k)}{R}} \times \sqrt{h}$$

we then get the angle of depression

$$d = z \div 90° = 74.4 \sqrt{h}\,^{1})$$

where d is expressed in seconds, h in metres.

[1]) In "Formeln und Hülftafeln" Albrecht gives for $k = 0.13$

$$z \div 90° = 107.7 \sqrt{h}.$$

For the radius at the range of vision in the Greenland Sea by using $k = 0.584$ from the formula:

$$r = \sqrt{\frac{2R}{1 \div k}} \times \sqrt{h}$$

one gets

$$r = 5.54 \sqrt{h}\,^{1})$$

where r is expressed in kilometres, h in metres.

[1]) Albrecht gives for $k = 0.2$

$$r = 3.99 \sqrt{h}.$$

CHAPTER II.

Base Measurement and Triangulation.

Base Measurement.

The measurement was performed on an even plain in east-west, close to the north of the Observatory. The plain was throughout nearly the whole of its length irrigated by two brooks; the bottom was covered with stones, in places marshy and covered with grass.

The termini of the line were marked off by brass bolts, driven into the solid bed-rock. The bolts which penetrated about 6 cm into the rock and projected about 2 cm above it, had a cross filed into the surface, marking the termini ot the line. As the entire length of the line was nearly 1450 m, it was furthermore marked off by six iron plugs, adjusted into the line by means of a theodolite. Between the plugs a cord was strung for guidance in the subsequent tape measuring. When the measuring was commenced on September 24th, 1906, the bottom was everywhere frozen and partly covered by snow, and the rivers were frozen over.

The measuring was performed by a steel tape, 24 m long. Adjunct to the tape were six iron plugs as well as a small, 5 m long steel tape in a leather case. The ends of the long tape were marked by the plain front part of a brass cross-piece; the tape was further provided with rough marks for every metre, but the latter were not used. The small tape was divided into centimetres; besides the first decimetre was divided into millimetres.

The length of the tape had been determined on the standard base of the General Staff in Proviantgaarden, Copenhagen, in the following manner:

To the two ends of the tape a millimetre rule drawn on paper was pasted. One of these rules was placed arbitrarily against the one terminus of the standard base, after which the tape was stretched by an even pull, which was estimated at 5 kg. The tape was supported on the middle on a level with the line between the termini of the base; but the two halves of the tape were otherwise suspended without any support. By pulling very hard, one might increase the

length of the tape by a few millimetres, in that the tape was then stretched and the curves somewhat straightened out.

Standardization of the 24-metres steel tape on 11/VI 1906.
Length of standard base: $b = 23.96870$ m; $t = +19°$ C.
Length of tape (in millimetres).

$$\begin{aligned} &1.\ b + 9.7 + 17.5 = b + 27.2 \\ &2.\ b + 10.0 + 17.5 = b + 27.5 \\ &3.\ b + 15.0 + 14.0 = b + 29.0 \\ &4.\ b + 8.5 + 20.0 = b + 28.5 \\ &5.\ b + 12.5 + 14.5 = b + 27.0 \end{aligned}$$

After this the length of the tape at $+19°$ C

$$L_{+19°} = 23.9965 \pm 0.0009 \text{ m}.$$

The co-efficient of expansion of the tape was rated at 0.0000136. Our base in Greenland was measured six times in the course of the autumn 1906.

I. 26/IX 06, afternoon. The temperature of the earth and the snow varied from $\div 9°.0$ to $\div 7°.0$; the temperature of the air varied from $\div 8°.0$ to $\div 7°.3$. The temperature of the tape was estimated at $\div 7°$. Length of the base

$$B = 60\, L_{\div 7°} + 10.621 \text{ m} = \frac{1450.411}{1.00035} \text{ m}.$$

II. 27/IX, forenoon. The temperature of the earth and the snow from $\div 7°.1$ to $\div 7°.0$; temperature of the air from $\div 7°.3$ to $\div 5°.8$. The temperature of the tape was estimated at $\div 6°$.

$$B = 60\, L_{\div 6°} + 10.680 \text{ m} = \frac{1450.470}{1.00034} \text{ m}.$$

III. 27/IX, afternoon. The temperature of the earth and the snow from $\div 7°.5$ to $\div 9°.0$; the temperature of the air from $\div 6°.5$ to $\div 7°.0$. The temperature of the tape was estimated at $\div 7°$.

$$B = 60\, L_{\div 7°} + 10.829 \text{ m} = \frac{1450.619}{1.00035} \text{ m}.$$

IV. 28/IX, forenoon. The temperature of the earth and the snow from $\div 7°.0$ to $\div 5°.4$; the temperature of the air from $\div 6°.0$ to $\div 4°.5$. The temperature of the tape was estimated at $\div 5°$.

$$B = 60\, L_{\div 5°} + 10.843 \text{ m} = \frac{1450.633}{1.00033} \text{ m}.$$

V. 28/IX, afternoon. The temperature of the earth and the snow $\div 4°.5$; the temperature of the air from $\div 3°.3$ to $\div 3°.5$. The temperature of the tape was estimated at $\div 3°$.

$$B = 60\, L_{\div 3^0} + 10.770 \text{ m} = \frac{1450.560}{1.00031} \text{ m}.$$

VI. 29/IX, afternoon. The temperature of the earth and the snow $\div 6°.5$; the temperature of the air from $\div 5°.0$ to $\div 6°.5$. The temperature of the tape was estimated at $\div 5°$.

$$B = 60\, L_{\div 5^0} + 10.489 \text{ m} = \frac{1450.279}{1.00033} \text{ m}.$$

I	1449.90
II	1449.98
III	1450.11
IV	1450.16
V	1450.11
VI	1449.80
	0.06

Result: $B = 1450.01 \text{ m} \pm 0.14 \text{ m}$.

In the spring of 1907 an attempt was made to improve the above value; but it failed. On March 20th and 21st the lines were measured three times at a temperature of the air and snow varying between $\div 19°$ and $\div 23°.5$. The ice in the soil was so hard, that the plugs could not be driven in; only where the surface was covered by snow, could we make the plugs stand, though even then they were very far from being sufficiently firm. Otherwise the rather low temperature did not hinder the work. The three measurings made in March were all condemned. After reduction for the temperature of the tape, which was estimated at $\div 20°$, the result was

VII	1449.64
VIII	1449.89
IX	1449.86.

The levelling of the base was performed by means of a Stampher levelling instrument, with horizontal sights from the exact middle. During this process the line was divided into eight sections, corresponding to the undulation of the country. If d stands for the section of the line measured and h for the dip of the country in the same section, whereas the horizontal distance corresponding to d is a, one has by the measuring of d committed the error $a \div d = \div 2\, d \sin^2 \frac{x}{2} = \div \frac{h^2}{2\, d}$.

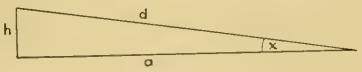


Fig. 24.

The result of the levelling is given in the table below.

From this it appears that the value found for the base is to be reduced by 0.02 m, after which the final value becomes:

$$B = 1449.99\,\text{m} \pm 0.14\,\text{m}.$$

	d	h	$\frac{h^2}{2d}$
1....	121	÷ 1.00	0.004
2....	180	÷ 1.90	0.010
3....	182	+ 0.58	0.001
4....	197	÷ 0.60	0.001
5....	226	÷ 0.96	0.002
6....	226	+ 0.23	0.000
7....	230	÷ 0.07	0.000
8....	88	+ 0.71	0.003
	1450	÷ 3.01	0.021

Before the expedition left Greenland, we built little cairns over the brass bolts in the termini of the base.

Experience gained. It was hardly correct, when in the course of the standardization it was deemed sufficient to support the middle of the tape; it ought to have been supported throughout its entire length, because this corresponds more immediately with the conditions under which the measuring takes place. Nor was it correct when it was deemed sufficient to estimate the strain; it ought to have been measured with a little dynometer (spring steelyard) at each end. In the course of the measurement of the base line it gave us a feeling of uncertainty that we did not know for certain, how much we ought to stretch the tape, which uncertainty was all the more apparent, because we were repeatedly obliged to change our staff. The here-mentioned minor drawbacks have, however, hardly been of any importance from a practical point of wiew.

A tape measurement ought to be performed during the autumn, before the beginning of the heavy fall of snow, and before the soil becomes too hard. Quite exceptionally one will, to great advantage, be able to perform a tape measuring on the new ice, and measurings of this kind were performed several times on the sledge trips. However, in such circumstances one ought not to use plugs, but instead of that mark off the termini of the tape by means of a fine scratch in the ice.

Triangulation. Surveying Operations.

Not until the beginning of September was it possible to commence the triangulation, and from October 1st I was to be ready to commence the sledge-trips for laying down depots. During the month at my disposal the triangulation was to be carried so far towards west and south that during the fotlowing summer we could carry the triangulation net further from Orienteringsöerne (the orientation islands) and the interior of Dove Bugt (Dove bay). Thus as early as September 1906 we had to determine the position of stations on

Varderyggen (the cairn ridge), Harefjeldet (the hare hill) and on the west side of the northern part of Store Koldewey. We were very lucky in so far, as we really succeeded in doing this.

The reconnoitring was performed in a very systematic manner. First of all we selected a line, which lent itself to the base measurement. As we lacked the means of making a particularly careful centration of the instrument and of a very accurate putting up of signals, it was necessary to make the base comparatively long. A suitable terrain for the base was found at once, immediately north of the Observatory. From the termini of this line a very cursory angle measuring was made by means of a theodolite at certain points in the neighbourhood, which might be supposed to be suitable for stations (Harefjeldet, Thermometerfjeldet, Østre and Vestre Havnenæs), and from there again corresponding rough angle measurements were made. The results of the measurements were, by means of a protractor, marked off on a piece of paper, in which manner a preliminary "graphic" triangulation net was provided, which furnished excellent guidance at the determination of the localities, in which the nearest and a good number of the more remote stations were to be selected.

After that we at once set about building the cairns at the stations III, IV, IX and XI. This was done in the following manner:

In order to create a permanent station mark a hole, about 6 cm deep, was made in the solid rock by means of a hammer and stone bore. Into this a prismatic brass bolt, 8 cm long, was driven right home. On the brass bolt a bamboo stick, about $2^1/_2$ m long, was placed in a vertical position and supported by means of three stays made of wire. Using the bamboo stick as an axis the cairn was built on a circular base with a radius of $^3/_4$ to 1 metre; the height of the cairn was generally about 2 m. At the stations III, IV, IX and XI, which were comprised in the base network, particular care was taken to adjust the bamboo stick vertically, and in order to provide a sharp sighting point a cylindrical tin was placed on the bamboo stick above the cairn (Fig. 25).

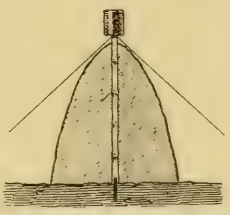


Fig. 25.

The rest of the reconnoitring work with the adjunct building of cairns — that is in the case of the first twelve stations with the exception of Station X — was performed on a motorboat trip during the early part of September. As in the course of this trip it proved difficult, from the more remote stations, to point some of the low-lying cairns in the neighbourhood of the base, because they merged into the background, these cairns were covered with white linen. (For the purpose we had brought 60 m^2 of linen).

The instrument with which the measurement of angles was performed, was a small universal instrument supplied by Max Hildebrand, Freiberg, Sachsen. The telescope had an objective aperture of 2 cm, 15 cm focal length, and fourteen times magnifying power. To the telescope belonged a diagonal eye piece with coloured glass. The horizontal circle, the diameter of which was 8 cm, was divided into half degrees with vernier reading in whole minutes. The vertical circle, the diameter of which was $9^1/_2$ cm, was divided into thirds of degrees with vernier reading in half minutes. The divisions on both circles and on the verniers were so accurate and sharp, and the single parts of the instrument fitted so well together that the reading could be estimated rather accurately in tenths of a minute. The divisions on the level of the vertical circle were nearly 20″, on the level of the axis nearly 30″. Both levels were provided with an air chamber, a necessary precaution on arctic travels; also all the screws and the settings of the eye pieces were covered with ebonite, as they were to be used in a low temperature.

By means of a central screw with a spiral spring the instrument was fastened to a tripod; the three levelling screws rested in slits on the head of the tripod. The legs of the latter were telescopic, but nevertheless sufficiently stiff for the purpose. In windy weather, however, a bag filled with stones was suspended between the legs of the tripod in order to increase the stability.

To the instrument belonged a compass, by means of which we could make rough determinations of the magnetic declination.

The expedition carried six of these small universal instruments, to be used in the course of the geographical survey. These small instruments are ideally suited for use on sledge trips. Their concentrated construction and excellent packing enable them to bear the rough handling, which they are necessarily subjected to on sledge trips. The packing method might, however, be a trifle improved. Thus it would be an advantage, if the diagonal eye piece could remain screwed on to the telescope, when the instrument was packed in its box, and likewise that the objective end of the telescope was clamped on to the shelf of the box, on which the instrument stands, for instance by means of a hasp or in some similar way. During the constant and violent shakings on a sledge trip in pack ice it must be borne in mind that the clamp of the telescope may easily become loosened, in which case the objective end is made to clash with the back wall of the box of the instrument, whereas the diagonal eye piece, when attached to the telescope, is made to rub against the shutter of the box. The effects of this became, in their turn, a slight twisting of the horizontal circle or bending of the

horizontal axis, excentricity of the horizontal circle or parallax of the verniers.

The measurement of angles was performed as is shown by the following table of observations. The horizontal angles were measured by the "method of directions" in three sets. In the case of points which were not marked off as triangulation points, only two sets were measured. The cairn at the actual station, where the measuring took place, entered into the series of the points observed, in respect of the determination of the elements of centration; and in order to eliminate all doubt on later occasions as regards the position of the instrument, a sketch was likewise made of the position of instrument and station cairn and with an indication of the direction at one of the other cairns. Not until the three horizontal sets had been fully measured, were the vertical angles observed. By means of this arrangement one achieves a more accurate measuring of the horizontal angles, among other things because the attention has not at the same time to be strained by the measuring of the vertical angles. For the vertical angles only two levellings were used.

All that in the table is put with italics is recorded in the field; the rest is entered in the observation journal at home, before and after the actual surveying operations.

As the dimensions of the cairns were entered in a pocket book during the reconnoitring trips, they are not given in the observation journal. They ought, however, to have been mentioned here, as we should then have had all the particulars necessary for the computation collected in one place (The height of the cairn plays a part, in case it is the top that has been pointed. As a general rule the foot of the cairn was pointed).

Attention is drawn to the fact that the four upper readings of the level correspond to the first levelling, the four lower ones to the second levelling. As the two observations of the level are computed together (example: in the case of Cairn VIII $4.4 + 12.7 + 5.0 + 14.2 = 36.3$ and $11.2 + 2.3 + 10.6 + 1.5 = 25.5$) a direct comparison between the two values of the vertical angle does not give a complete picture of the accuracy arrived at. Nor is this necessary. The object of the two levellings is first and foremost to secure oneself against grave mistakes in the reading, and this security is obtained.

The centration corrections noted in the case of the means appear from a special computation, further particulars of which will be given below.

It has already been mentioned that the triangulation net does not contain a base net in the ordinary acceptation of the term, and that in the small triangles I contented myself with providing very

Lille Koldewey, Station V, 18/IX 1906, afternoon, t = ÷ 7°, wind 1—2, eccentric position, altitude of telescope above the foot of the cairn 1.2 m.

Point	Vernier	Set 1	Set 2	Set 3	Vernier	Levelling 1	Levelling 2	Level Obs.	Level Obj.	Remarks
	I	*232°31'.9*	*112°29'.7*	*352°28'.8*	A	*87°17'.6*	*87°17'.8*	*1.0*	*10.2*	*The foot of cairn*
	II	*32.2*	*29.9*	*28.8*	B	*17.8*	*17.7*	*11.5*	*2.6*	
	II	*32.1*	*29.9*	*29.0*		87 17.70	87 17.75			
	I	*31.7*	*29.8*	*28.8*	A	*272 42.7*	*272 42.5*	*4.6*	*12.7*	
VI		127.9	119.3	115.4	B	*42.4*	*42.3*	*12.0*	*3.0*	
						272 42.55	272 42.40			
		232 31.98	112 29.83	352 28.85		174 35.15	174 35.35	29.1	28.5	
						174°35'15"				
Mean		00 00 00 + 21"				87°17'38" + 0.6 × 20".5/8				
Centred		00°00'00"				87°17'40"				
	I	*311°13'.7*	*191°11'.8*	*71°11'.0*	A	*88°33'.6*	*88°33'.8*	*4.4*	*12.7*	*The foot of cairn*
	II	*13.8*	*11.9*	*11.2*	B	*33.6*	*33.6*	*11.2*	*2.3*	
	II	*14.3*	*11.3*	*11.2*		88 33.60	88 33.70			
	I	*13.8*	*11.3*	*11.2*	A	*271 26.5*	*271°26.5*	*5.0*	*14.2*	
VIII		55.6	46.3	44.6	B	*26.4*	*26.4*	*10.6*	*1.4*	
		311 13.90	191 11.58	71 11.15		271 26.45	271 26.45	25.5	36.3	
		78 41.92	78 41.75	78 42.30		177 07.15	177 07.25			
				297		177°07'12"				
Mean		78°41'59" ÷ 00"				88°33'36" ÷ 10.8 × 20".5/8				
Centred		78°41'38"				88°33'08"				
	I	*359°25'.4*	*239°22'.9*	*119°22'.3*	A	*89°26'.0*	*89°26'.1*	*1.5*	*10.6*	*The foot of cairn*
	II	*25.4*	*23.1*	*22.6*	B	*25.8*	*26.2*	*13.3*	*4.2*	
	II	*25.9*	*22.6*	*22.3*		89 25.90	89 26.15			
	I	*25.5*	*22.6*	*22.5*	A	*270 34.5*	*270 34.3*	*2.0*	*11.3*	
VII		102.2	91.2	89.7	B	*34.3*	*34.2*	*12.0*	*2.8*	
		359 25.55	239 22.80	119 22.43		270 34.40	270 34.25	32.3	25.4	
		126 53.57	126 52.97	126 53.58		178 51.50	178 51.90			
				112		178°51'42"				
Mean		126°53'22" ÷ 30"				89°25'51" + 6.9 × 20".5/8				
Centred		126°52'31"				89°26'09"				
	I	*6°26'.7*	*246°24'.5*	*126°23'.7*	A	*89°13'.7*	*89°14'.4*	*1.3*	*10.5*	*The foot of cairn*
	II	*26.7*	*24.8*	*23.8*	B	*13.8*	*14.3*	*13.0*	*3.8*	
	II	*26.8*	*23.7*	*23.9*		89 13.75	89 14.35			
	I	*26.6*	*23.8*	*23.9*	A	*270 46.6*	*270 46.4*	*1.8*	*11.0*	
X		106.8	96.8	95.3	B	*46.4*	*46.2*	*12.0*	*2.8*	
		6 26.70	246 24.20	126 23.83		270 46.50	270 46.30	31.6	24.6	
		133 54.72	133 54.37	133 54.98		178 27.25	178 28.05			
				207		178°27'39"				
Mean		133°54'41" ÷ 14"				89°13'50" + 7.0 × 20".5/8				
Centred		133°54'06"				89°14'08"				

Point	Vernier	Set 1	Set 2	Set 3	Vernier	Levelling 1	Levelling 2	Level Obs.	Level Obj.	Remarks
	I	*6°45'.1*	*246°42'.7*	*126°42'.0*	A	*89°45'.8*	*89°45'.5*	*3.0*	*12.2*	*The foot of cairn*
	II	*45.3*	*42.9*	*42.2*	B	*45.8*	*45.3*	*9.5*	*0.5*	
	I	*45.2*	*42.0*	*42.2*		89 45.80	89 45.40			
	II	*44.9*	*42.0*	*42.0*	A	*270 14.8*	*270 15.2*	*1.0*	*10.0*	
IX		180.5	169.6	168.4	B	*14.6*	*14.8*	*11.5*	*2.5*	
		6 45.13	246 42.40	126 42.10		270 14.70	270 15.00	24.0	26.2	
		134 13.15	134 12.57	134 13.25		179 31.10	179 30.40			
				297		179°30'43"				
Mean		134°12'59" ÷ 20"				89°45'23" ÷ 2.2 × 20".5/8				
Centred		134°12'18"				89°45'17"				
	I	*34°03'.6*	*274°01.0*	*154°00'.2*	A	*90°11'.8*	*90°12'.4*	*1.0*	*10.2*	*The foot of cairn*
	II	*03.4*	*01.2*	*00.8*	B	*11.7*	*12.3*	*12.8*	*3.6*	
	I	*03.0*	*00.2*	*00.6*		90 11.75	90 12.35			
	II	*02.7*	*00.3*	*00.5*	A	*269 48.6*	*269 48.3*	*1.0*	*10.3*	
XII		12.7	02.7	02.1	B	*48.4*	*48.3*	*11.3*	*2.3*	
		34 03.18	274 00.68	154 00.53		269 48.50	269 48.30	30.0	22.5	
		161 31.20	161 30.85	161 31.68		180 23.25	180 24.05			
				73		180°23'39"				
Mean		161°31'15" ÷ 42"				90°11'50" + 7.5 × 20".5/8				
Centred		161°30'12"				90°12'09"				
	I	*66°22'.2*	*306°20'.2*		A	*90°43'.7*	*90°43'.6*	*4.5*	*12.6*	*The foot of cairn*
	II	*22.4*	*20.4*		B	*43.6*	*43.7*	*11.8*	*2.6*	
	II	*22.0*	*19.6*			90 43.65	90 43.65			
	I	*21.9*	*19.8*		A	*269 16.4*	*269 16.4*	*2.5*	*11.8*	
Maroussia		88.5	80.0		B	*16.4*	*16.2*	*11.3*	*2.3*	
		66 22.13	306 20.00			269 16.40	269 16.30	28.0	31.4	
		193 50.15	193 50.17			181 27.25	181 27.35			
						181°27'18"				
Mean		193°50'10" ÷ 1'07"				90°43'39" ÷ 3.4 × 20".5/8				
Centred		193°48'42"				90°43'30"				
		128°43'	*8°40'*							
		132°11'	*12°30'*							
Station cairn		130 27	10 35			*The distance from the instrument to the centre of the cairn is 1.90 m*				
		257 55	258 05							
Mean		258°00'								

sharp sighting points, while I also determined the elements of centration with special care. As regards the two termini of the base Fig. 26 gives an idea of the manner of proceeding used in this case. A tin cylinder about 0.7 m high was placed in a position as accurately centred as possible above the brass bolt; on the tin cylinder was

placed — also very accurately centred — a cylindrical food tin painted white. The signal thus provided was kept in place by means of iron wire stays. During the observation the tripod was placed above the signal, and the instrument was centred by means of a plumb, the cord of which was fastened to the hook of the central screw. The cord was passed through a hole in the surface of the signal, and the position of the plumb in proportion to the brass bolt was controlled through two segments in the lower part of the surface of the cylinder (see Fig. 26).

Fig. 26.

It was at the very last moment that the triangulation was carried out. When on September 20th we returned from our last boat trip, we had repeatedly been forced to use ice-transport, and finally we had to cut and break the new ice for the last two kilometres in the harbour. On two occasions we had further been obliged to drag the boat across the small isthmus in the middle of Lille Koldewey, as the ice had blocked our passage round the island. Besides the fall of snow had begun to make the ascent of mountains more difficult. The last station, the Observatory, was measured on September 28th, and so we had attained the object aimed at and collected observation material, the computation of which would form a suitable occupation during the approaching winter.

The starting point of the levellings was the zero of the tidal gauge of the expedition near the ship. From here the levelling was carried on during the last days of September across the ice to land, by means of a Stampher levelling instrument with horizontal sights from the middle. After that the levelling was carried on in a loop by the Observatory and both of the termini of the base. The result was:

The Observatory, the brass bolt in the surface of the granite pillar 13.46 m
The western end of the base, the brass bolt ..... 14.27 -
The eastern end of the base, the brass bolt ..... 11.26 -

The triangulation 1907—08. The many sledge trips undertaken in the course of the autumn of 1906 and the spring of 1907 had gradually given us a fair knowledge of the lay of the land, and further it had made rather clear to us what tasks lay before us, and how they ought to be tackled. The intricate belt of rocks in Dove Bugt made it desirable to extend the triangulation net towards west, aiming at the same time to go south with the network as far as Haystack. This point had been determined by triangulation by the Germania-Expedition in 1870, and we might thus, if the connection with Haystack was established, benefit by the excellent determination of longitude made by the Germania-Expedition in the Pendulum Islands.

During the great sledge journey undertaken in the spring of 1907 we succeeded in keeping up the connection by means of azimuths from station to station, all the way from 77°15′ (the northern part of Germania Land) to 80°43′ (Amdrups Land), so that the determinations of longitude on this long coast became practically independent of our watches. On the other hand this connection by means of azimuths was lacking on the comparatively short distance from Danmarks Havn to the northern part of Germania Land, and for this reason among others it was desirable to carry the triangulation net in a northern direction along the outer coast of Germania Land as far as Kap Marie Valdemar.

The circumstance that Mylius-Erichsen and his sledge party were lost[1]) caused, however, a very great modification in these plans.

[1]) This disaster meant a very serious loss to the survey work. I lost Hagen, who was exclusively at my disposal. B. Thostrup, who after Mylius-Erichsen took charge of the ethnographic work, had only comparatively little time to spare for surveys. G. Thostrup and Lindhard, in the autumn of 1907, went north with six sledges in order to search for Mylius-Erichsen, in which manner I was deprived not only of my staff, but also of dogs; and finally I went north myself, in March 1908, in order to try to obtain news of our missing com-

First and foremost the attempt had to be made to bring the geographical survey to a natural finish, and this task in itself so fully engrossed the staff at my disposal for the survey work, that all systematic triangulation had to be given up.

Under these circumstances the triangulation work as continued came to be limited to a trigonometric station pointing (the problem of Pothenot) of the points, the position and altitude of which we desired to determine with regard to the geographical survey work. The station points were not marked off with brass bolts; but after the conclusion of the survey a cairn was built, which could then be used as a fixing point in the later trigonometric station pointings. In this manner Snenæs (XVI), Nordre Orienteringsø (XIV), Søndre Orienteringsø (XV), Moskusoksefjeldene (XXIII), Trekroner (XIX), Hvalrosodden (XXI), Brystet (XX), Rypefjeldet (XXII) and Teufelkap (XXIV), as well as a few points on the outer coast of Germania Land, were joined to the triangulation net as stations, and besides a very large number of points in the ground, offering natural, sharp sighting points were determined by bearings with three or more sights, among others Haystack and Kap Récamier and Rekvedøen (driftwood island) in Skærfjorden (the skerry fjord).

The object aimed at in the triangulation work might thus be said to have been achieved, and as regards the map made of Dove Bugt etc. and the computation of the altitudes of mountains, the accuracy was fully sufficient; on the other hand I dared not a priori depend upon the connection with Haystack being so good, that I could in this manner compute the longitude, and in the autumn of 1907 I consequently had to have recourse to the difficult astronomical determination of longitude by means of observations of the moon.

The horizontal as well as the vertical angles were in 1907—1908 measured in the same manner as in the autumn of 1906; but as the sides of the triangles had gradually increased, until they were upwards of 40 kilometres, we could no longer — particularly in respect of the unstable conditions of refraction — depend upon the altitudes computed, even though the control was satisfactory. At Hvalrosodden (walrus point), where the height of the station was only 2 m, the levelling was determined by measuring at a point on the coast, estimated to be situated in the mean sea level, and from there carried to the stations in the inner part of Dove Bugt.

rades. In other circumstances the survey work would have benefited by a very considerable part of the labour which was lost with the sledge party of Mylius-Erichsen or employed in searching for the latter.

The computation of the triangulation net.

For several reasons, and among other things because the cairns were to be used as fixing points when drawing up a minute map of the surroundings of Danmarks Havn, we had as early as the winter of 1906—07 been obliged to undertake a computation of the then existing triangulation net.

As I had to reckon without assistance, I divided my triangulation work into groups of triangles, and finished the single group altogether, before passing on to the next. The groups were determined with a view to the fact that the sides of each triangle had to be computed through two sets of triangles, and of these the one set was all through to have a favourable form. The few computations, the nature of which did not permit of a satisfactory control — as for instance certain calculations in the observation journal, computations of eccentricity and the like — were calculated twice with an interval of at least twenty-four hours.

Eccentricity. At nearly all of the stations it had been necessary to perform the measuring of angles from a point lying outside the centre of the station (the axis of the cairn), and consequently it became necessary, by a short computation, to convey the bearings measured to the centre of the station. To be used for this purpose the sides of the triangles were at first roughly computed with a four-placed table, by means of the angles measured. As an example I shall here give the computation of eccentricity in the case of a single station. In the case of Station V the provisional computation of the sides of the triangles gave the following values:

Side	log Side
V— VI	4.2582
— VII	3.9991
—VIII	4.0684
— IX	4.2144
— X	4.3540
— XII	3.9678
—Maroussia..	3.7225

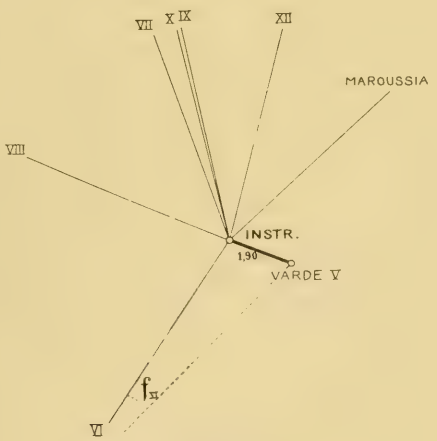


Fig. 27.

In order to convey the bearing measured, Instr.—VI, to the centre of the cairn (Varde V, Fig. 27) we had to apply the correction f_{VI} determined by:

$\sin f_{VI} = \frac{1.90 \sin 102°00'}{\{4.2582\}}$ [1]) (cf. extrait of observation journal p. 206);

$$f_{VI} = + 21''.$$

In a similar manner we get the other corrections:

$$\sin f_{VIII} = \frac{1.90 \sin 180°42'}{\{4.0684\}}; \quad f_{VIII} = \div 00''$$

$$\sin f_{VII} = \frac{1.90 \sin 228°53'}{\{3.9991\}}; \quad f_{VII} = \div 30''$$

$$\sin f_{X} = \frac{1.90 \sin 235°55'}{\{4.3540\}}; \quad f_{X} = \div 14''$$

$$\sin f_{IX} = \frac{1.90 \sin 236°13'}{\{4.2144\}}; \quad f_{IX} = \div 20''$$

$$\text{siu } f_{XII} = \frac{1.90 \sin 263°31'}{\{3.9678\}}; \quad f_{XII} = \div 42''$$

$$\sin f_{M} = \frac{1.90 \sin 295°50'}{\{7.2225\}}; \quad f_{M} = \div 1'.07''$$

In order not to mistake the sign and to make sure against gross errors of calculation one ought, by means of a protractor, to draw a careful sketch of the station, such as indicated above (Fig. 27). When it is borne in mind that the graduation of the theodolite follows the same direction as that of the watch it appears at once that the correction of the bearing Instr.-VI must be positive (i. e. if one had had one's instrument placed on the cairn, the reading off for the bearing at Point VI would have become greater) and also that the other corrections must be negative.

When the eccentricity of a station is computed, it is entered in the observation journal as shown on the table pp. 206—207, and after that the centred set is computed.

The base net.

In the group of triangles, of which the base net consisted, all the angles were measured. In this manner discrepancies arise, in that the sums of the angles of the single triangles should be 180 [2]). To undertake an elaborate, systematic adjustment of the observations in order to comply with the geometric conditions would, however, be rather irrelevant. Considering the object of the triangulations, a

[1]) { } shows that the logarithm has been indicated in stead of the corresponding number.

[2]) In triangles as small as those of the base net the spherical excess is only just a fraction of a second; but even in the biggest triangles one may at a triangulation of this kind ignore the spherical excess altogether.

computation of this kind would be loss of time, and besides the basis of a scientific treatment can hardly be said to exist. The forced work during the survey did not permit us to pick and choose our weather; we had to survey under all sorts of weather conditions, even in storm and at a low temperature, and consequently there was no a priori reason to suppose that the survey work done at the various stations possessed the same degree of accuracy. Add to this that there was a considerable difference between the certainty with which the cairns could be pointed, so that we could not even reasonably take it for granted that the bearings from the single stations were determined with nearly the same sharpness.

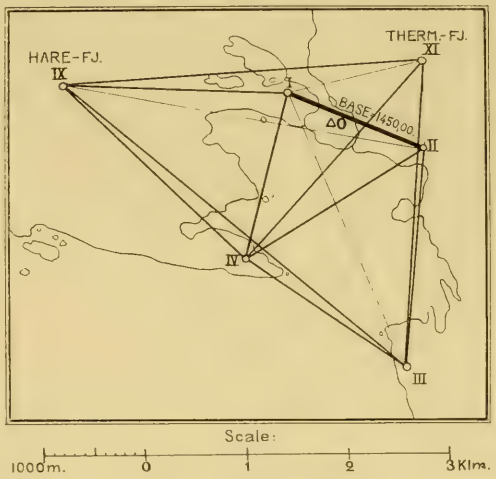


Fig. 28. The base net.

When the bearings had been corrected for eccentricity, one might have rested content with this and thus have left out the adjustment altogether, without the accuracy of the results suffering thereby to any considerable extent; but the fact that observer and computer were one and the same person, that the observation journal contained full particulars of the circumstances under which the survey had taken place on the stations, and that the computation followed so quickly upon the survey that we still had a lively recollection of the details of the latter, made it rather probable that by a purely practical estimate one would be able to increase the accuracy by adding such corrections to the angles that the sums of the angles became 180° in the triangles, through which the computations were carried. A direct profit from this would be — besides the somewhat problematical increase of the accuracy — that it would be possible to control the computations of the single triangles. This latter circumstance is of no small importance from a practical point of view, in particular when one has to make one's computation without an assistant.

A treatment of the observation material as here proposed has no bearing on the systematic adjustment; it will always be a somewhat arbitrary correction on the angles, partly determined by the knowledge possessed by the computer of the circumstances under

which the survey has taken place. An example of such a regulation of the angles is given below.

The object of the computation of the base net was the best possible determination of the sides of the triangle III—IX—XI. In order to suffer the smallest possible loss of accuracy, the computation was carried on through the triangles which had the most favourable form (i. e. approached most nearly to the equilateral triangle).

These triangles are in Fig. 28 drawn with a thick line.

The computation was carried out from the base through the triangles I—II—IV, I—IV—IX and II—III—IV to the sides IV—IX and III—IV; from there through IV—IX—XI and III—IV—XI to triangle III—IX—XI. The smallest angle which in this manner entered into the computation was, as will appear below, about 38°, the greatest about 88°; by the double computation of the side III—IX one might, therefore, lay claim to have a good control.

It was, however, a practical proceeding to compute all the sides of the net in respect of the subsequent construction of the points on the plane table and map. The further computation of the net, therefore, included the triangles I—III—IX and II—III—IX with control at the side III—IX, as well as the triangles I—II—XI and I—IV—XI with control at the side IV—XI. Triangle II—IV—XI was avoided, because it contained an angle of about 17°.

Before the actual computation could begin, the above-mentioned correction of the angles had to be undertaken in a lump for all of the triangles in the base network, through which the computations were to be carried; only in this manner could we protect ourselves against the possibility of corrections in certain triangles leading to absurd consequences in others. Therefore, as indicated below, a summary was made of all the angles, and in this the corrections were added. For our guidance we had the following:

1. The cairn at Station IV had been difficult to point from all the other stations; the sights at IV, therefore, had to be considered less accurate.

2. The bearing IX—XI was rather uncertain; it had not been possible from IX to see the food tin marking the axis of cairn XI.

3. In the square I—XI—II—IV the sum of the angle was 360°00′02″. As the two triangles with the common side IV—IX only had the errors + 4″ and ÷ 6″ in the sums of the angles, whereas the other two had the errors + 11″ and ÷ 13″, it seemed most natural preferably to correct the bearings I—II and II—I. This harmonized with the fact that the sights I—II and II—I were less good. The signals of the stations I and II were painted white out of regard to the darkish soil; but on the night preceding the observations at those two

stations, snow had unfortunately fallen, whereby the white colour in reality on this occasion became a drawback.

Triangle I—II—IV		Triangle I—IV—IX		Triangle II—III—IV	
I	81°48′38″	I	77°30′12″	II	53°51′12″
II	54 09 50	IV	60 54 56	III	60 12 46
IV	49 01 21	IX	41 34 34	IV	65 56 28
	179°59′49″ + 11″		179°59′42″ + 18″		180°00′26″ ÷ 26″

Triangle IV—IX—XI		Triangle III—IV—XI		Triangle III—IX—XI	
IV	87°58′46″	III	58°48′16″	III	53°39′00″
IX	47 54 08	IV	82 54 09	IX	43 55 34
XI	44 07 37	XI	38 17 50	XI	82 25 27
	180°00′21″ ÷ 21″		180°00′15″ ÷ 15″		180°00′01″ ÷ 01″

Triangle II—III—IX		Triangle I—III—IX	
II	95°28′16″ + 01″	I	115°04′40″ + 05″
III	55 03 30 + 00	III	27 19 05 + 05
IX	29 28 12 + 01	IX	37 36 00 + 05
	179°59′58″ + 02″		179°59′45″ + 15″

Triangle I—II—XI		Triangle I—IV—XI	
I	37°14′16″ ÷ 04″	I	119°02′54″ + 02″
II	67 11 51 ÷ 06	IV	27 03 40 + 00
XI	75 34 06 ÷ 03	XI	33 53 22 + 02
	180°00′13″ ÷ 13″		179°59′56″ + 04″

A glance at the corrections shows how the above-mentioned principle has been applied. As it will, however, always be doubtful whether the degree of accuracy is really increased by the proceeding indicated, it would perhaps have been better, and under all conditions simpler, if we had distributed the error of the sums of the angles in every single triangle, a third to each angle, quite irrespective of the possibility that the errors of the different triangles might come to clash with each other. As an example may be mentioned that the correction in triangle IV—IX—XI would in this manner become ÷ 7″ on each angle; in triangle III—IV—XI it would become ÷ 5″, whereas in triangle III—IX—XI it would become 0. But the angle XI in the latter triangle is the sum of the two angles XI in the two former ones, and it should consequently not have the correction 0 but ÷ 12″. A discrepancy of this kind is practically of no importance in the case of a triangulation so rough as the one in question, as long as the form of the triangles is favourable (ɔ: no angle less than 30°).

The computation of the triangle itself is a simple application of the sinus-formula for plane triangles. In this place it is therefore only to be put forward as an example illustrating a single triangle.

At the computation we made use of an assumed base length of 1450.00 m; this, however, deviates so little from the final value of 1449.99 m $\pm$ 0.14 m, that there is no reason to correct the lengths of the sides as computed in Greenland. The computation was performed with five-placed table; six decimals would only have made the computation more elaborate, without any corresponding increase of accuracy.

Triangle I—II—IV.

I	81°48′44″	log I—II . .	3.16137		
II	54 09 55	log sin IV . . .	9.84195		
IV	44 01 21		3.31942		3.31942
		log sin I	9.99555	log sin II . .	9.90887
		log II—IV . . .	3.31497	log I—IV . . .	3.22831

Summary of the rate of the computation of the sides of the base net.

Triangle	log Side		Remarks
I— II—IV	I—IV	3.22831	
	II—IV	3.31497	
I—IV—IX	I—IX	3.34783	
	IV—IX	3.39596	
II—III—IV	II—III	3.33704	
	III—IV	3.28365	
IV—IX—IX	IV—IX	3.42359	*a*
	IX—XI	3.55294	
III—IV—XI	III—XI	3.48811	
	IV—XI	3.42361	First control at *a*
III—IX—XI	III—IX	3.64309	*b* { Computed from the side IX—XI } concluding
	III—IX	3.64308	{ Computed from the side III—XI } control
I—III—IX	I—III	3.47151	
	III—IX	3.64306	Control at *b*
II—III—IX	II—IX	3.55877	
	III—IX	3.64312	Control at *b*
I— II—XI	I—XI	3.13995	
	II—XI	3.95713	
I—IV—XI	IV—XI	3.42360	Computed from I—XI } Control at *a*
	IV—XI	3.42360	Computed from I—IV }

The control in the first section, concluding with the computation of the big triangle III—IX—XI is a good one; in the last section it is complete, in the two triangles I—III—IX and II—III—IX it is satisfactory.

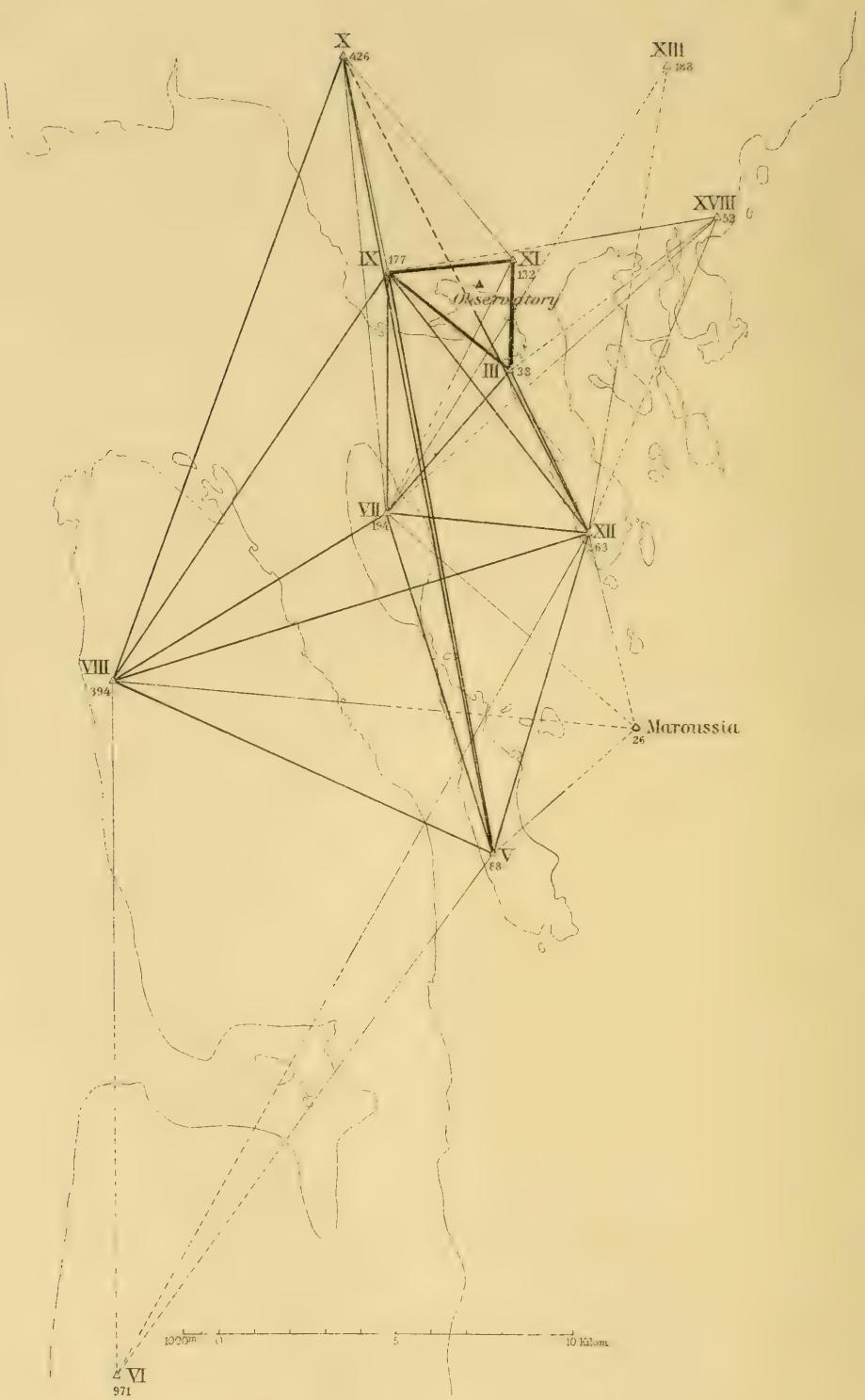


Fig. 29. The net of triangles of 1906.

The triangulation net proper.

In the sketch Fig. 29 of the net of the triangles, the usual manner of drawing is adopted. That the side VII—X is drawn in a full line thus means that Cairn VII has been pointed from X, and that also Cairn X has been pointed from VII. On the other hand the presentment of the side X—XII indicates that Cairn X has been pointed from XII, whereas Cairn XII has not been pointed from X. It thus appears direct from the figure that no measurements have been made at the stations VI, XIII and M (Maroussia). Otherwise, as in the case of the base net, the triangles through which the progressive computations are carried have been drawn with a heavier line.

The side of departure (i. e. the side from which the computations start) is the side III—IX, computed through the base net, for which log III—IX = 3.64309 has been found. For the computation of triangle IX—X—XI, however, IX—XI is made to form the side of departure.

The manner in which the triangles were divided into groups during the computation appears from the following:

The quadrangle III—IX—VII—XII.

Triangle III—VII—XI		Triangle III—VII—XII	
III	86°37′54″	III	68°18′56″
VII	41 22 22	VII	54 09 34
XI	52 00 14	XII	57 31 19
	180°00′30″ ÷ 30″		179°59′49″ + 11″

Triangle III—IX—XII		Triangle VII—IX—XII	
III	154°56′50″ ÷ 10″	VII	95°31′56″ + 00″
IX	13 23 52 ÷ 11	IX	38 36 22 + 01
XII	11 39 49 ÷ 10	XII	45 51 30 + 11
	180°00′31″ ÷ 31″		179°59′48″ + 12″

Triangle III—IX—XII which was of course not to be used for the computation, was included in view of the regulation of the angles. In this regulation proper allowance has been made for a remark in the observation journal, which mentions as doubtful whether at the measuring of the direction VII—III it was really Cairn III that was pointed. This was, however, as indicated by the sum of the angles clearly the case.

The computation of the triangle gave as a control log IX—XII $= \begin{cases} 3.96424 \\ 3.96428 \end{cases}$. As there was some likelihood that the former value was the best, log IX—XII was fixed at 3.96425.

The quadrangle V—VIII—VII—XII.

Triangle V—VII—XII		Triangle V—VII—VIII	
V	34°37′11″ ÷ 03″	V	48°10′53″ + 02″
VII	66 04 52 ÷ 04	VII	76 00 02 + 03
XII	79 17 37 ÷ 03	VIII	55 48 58 + 02
	180°00′10″ ÷ 10″		179°59′53″ + 07″

Triangle VII—VIII—XII		Triangle V—VIII—XII	
VII	142°04′54″ ÷ 01″	V	82°48′34″ ÷ 01″
VIII	14 40 32 ÷ 01	VIII	41 08 26 + 03
XII	23 14 42 ÷ 06	XII	56 02 55 + 03
	180°00′08″ ÷ 08″		179°59′55″ + 05″

The triangle VII—VIII—XII was included in view of the regulation of the angles: it was not used in the computations which as a control gave log VIII—XII $= \begin{cases} 4.14631 \\ 4.14630 \end{cases}$ of which values the former was used.

The quadrangle V—VIII—IX—XII.

Triangle VIII—IX—XII		Triangle V—VIII—XII	
VIII	38°45′20″ ÷ 25″	V	82°48′34″ ÷ 01″
IX	72 08 45 + 03	VIII	41 08 26 + 03
XII	69 06 12 + 05	XII	56 02 55 + 03
	180°00′17″ ÷ 17″		179°59′55″ + 05″

Triangle V—IX—XII		Triangle V—VIII—IX	
V	27°17′54″ ÷ 04″	V	55°30′40″ + 03″
IX	27 32 59 ÷ 04	VIII	79 53 46 ÷ 22
XII	125 09 07 + 08	IX	44 55 46 + 07
	180°00′00″ + 00″		180°00′12″ ÷ 12′

The strikingly large corrections which have been made here in the triangles VIII—IX—XII and V—VIII—IX respecting the angles IX are caused by the fact that the bearing VIII—IX, in spite of the rather good agreement of the sums of the angles, has in reality not been measured. The facts of the case are: at the survey made from Station VIII the pointing of Cairn IX failed altogether in the first set, and as far as the other two sets are concerned there is the following entry in the observation journal: "The pointing uncertain; the cairn not visible; background unfavourable." However, the sharp form of Harefjeldet (Cairn IX) seen from the south made it possible to point Station IX fairly well, irrespective of whether one could distinguish the cairn or not. A test of the sight VIII—IX was thus necessary, and for this reason the computation of the quadrangle V—VIII—VII—XII was the first thing to be done. In the triangle VIII—IX—XII the two sides VIII—XII and IX—XII were determined. Furthermore the angle at XII was given, being the sum of angle VII—XII—IX and

angle VII—XII—VIII, the value of which angles had already been established at the previous computation.

Given in triangle VIII—IX—XII was thus:

$$\begin{aligned} \text{The angle XII} &= 69°06'17'' \\ 180° \div \text{XII} &= A + B = 110°53'43'' \\ {}^1/_2\,(A+B) &= 55°26'52'' \end{aligned}$$

$$\begin{aligned} \text{The side VIII—XII} &= a = 14005.8\ \text{m} \\ \text{The side IX—XII} &= b = 9209.8\ \text{m} \\ a + b &= 23215.6\ \text{m} \\ a \div b &= 4796.0\ \text{m}. \end{aligned}$$

From the known formula $\tan {}^1/_2\,(A \div B) = \frac{a \div b}{a + b} \tan {}^1/_2\,(A + B)$ was then computed

$$\begin{aligned} A &= \text{angle IX} = 72°08'49'' \text{ and} \\ B &= \text{angle VIII} = 38°44'55''. \end{aligned}$$

The value computed of angle IX corresponded, as it appears, very well with the value measured; the divergence practically only concerned angle VIII, and this harmonized well with the remark in the observation journal. The measured bearing VIII—IX was, therefore, condemned, or rather, which came to the same thing, the correction $\div 25''$ was applied to angle VIII in triangle VIII—IX—XII. In the same triangle the correction of angle XII was, by means of corrections in triangles treated on an earlier occasion, determined at $+ 11'' \div 6'' = + 5''$.

Triangle V—VIII—XII had already been used in the preceding group, and so the corrections in the last two triangles V—IX—XII and V—VIII—IX were in all essentials given.

The computation was first performed without making use of the less favourable triangle V—IX—XII; for the side V—IX was found as control $\log \text{V—IX} = \begin{cases} 4.21534 \\ 4.21534 \end{cases}$. After that the double computation of the side V—IX was performed through the triangle V—IX—XII, in which manner $\log \text{V—IX} = \begin{cases} 4.21534 \\ 4.21535 \end{cases}$ was obtained.

The quadrangle V—VIII—X—XII.

Triangle V—VIII—X		Triangle VIII—X—XII	
V	55°12'28'' + 06''	VIII	52°30'25'' + 03''
VIII	93 38 51 + 06	XII	79 40 34 ÷ 03
X	31 08 14 + 15	X	47°49'01''
	179°59'33'' + 27''		

At the regulation of the angles it has been taken into consideration that the measuring of Station X took place, before Cairn X

was built and with a centred instrument. The station was situated on a rather small ledge, projecting from the wall of the rock and with a vertical fall towards the valley. After the observation, during the building of the cairn, it proved difficult to make the axis of the latter coincide with that of the instrument. Therefore it is very likely that there is a small centration error in the angles of Station X.

Through the two recorded triangles a double computation of the side VIII—X was performed, which gave the result $\log \text{VIII—X} = \begin{cases} 4.26942 \\ 4.26940 \end{cases}$.

The accuracy attained.

Before I passed on to compute the sights at the stations VI, XIII and M, I endeavoured to find an expression for the accuracy attained. The single groups of triangles were, it is true, as will appear from the preceding, computed under a fully satisfactory control of observation and computation, but this did not exclude the fact that the errors from group to group might have accumulated and so have become quite considerable. An expression of the accuracy might be gathered by computing the side X—XI, partly direct from the base net through triangle IX—X—XI and partly from the side VIII—X through the triangles VII—VIII—X and VII—X—XI.

Triangle VII—VIII—X

VII	116°31′27″	+ 00″
VIII	37 49 53	+ 04″
X	25 38 35	+ 01″
	179°59′55″	+ 03″

The double computation of the side VII—X gave

$$\log \text{VII—X} = \begin{cases} 4.10542 \\ 4.10541 \end{cases}$$

Triangle VII—X—XI

X	34°42′26″
XI	112 32 50
VII	32°44′44″

The computation gave:

$\log$ X—XI = 3.87307

Triangle IX—X—XI

IX	96°14′02″	+ 03″
X	28 24 27	+ 05
XI	55 21 20	+ 03
	179°59′49″	+ 11″

The computation gave:

$\log$ X—XI = 3.87297.

The length of the side X—XI corresponding with the two logarithms is 7465.7 m and 7464.0 m. The difference between these two values, 1.7 m, is nearly $\frac{1}{4400}$ of the side X—XI. As the control has now been looked for on a side, which is placed so unfavourably as it could well be, in that the one value is found by a computation through the whole of the triangulation net and by using one triangle of a less favourable shape, it seems probable to estimate the un-

certainty with which the sides of the triangulation network are determined at less than $\frac{1}{10000}$ of the length of the sides. This corresponds well with the uncertainty of the base measured, in that the computed mean error 0.14 m is very nearly $\frac{1}{10000}$ of the base. It thus seems as if there has been a substantial harmony between the means used at the base line measurement and triangulation.

As far as the practical application of the triangulation net was concerned, the uncertainty with which it was encumbered was of no importance whatever.

The Cairns VI, M and XIII.

The position of Cairn VI was computed through:

Triangle V—VI—VIII		Triangle VI—VIII—XII	
V	78°41′38″	VIII	106°29′07″ + 03″
VIII	65 20 41	XII	43 47 47 + 00
VI	35°57′41″	VI	29°43′03″

The double computation of the side VI—VIII gave log VI—VIII $= \begin{cases} 4.29124 \\ 4.29124 \end{cases}$.

The position of Cairn M was computed through:

Triangle V—VII—M		Triangle V—XII—M	
V	66°56′11″ ÷ 02″	V	32°18′30″ + 01″
VII	31 32 07 ÷ 02	XII	30 19 15 ÷ 01
M	81°31′40″		117°22′15″

The double computation of the side XII—M gave log XII—M $= \begin{cases} 3.72255 \\ 3.72262 \end{cases}$.

The position of Point XIII. At a rather advanced stage of the triangulation process itself I determined to include Point XIII in our observations, because I estimated that this point which lay near the outer coast might be of some importance, among other things in the case of a possible continuation of the triangulation net in a northern direction along the coast. No cairn had been built in this place, but as Point XIII was a hill of a rather regular domelike shape, I hoped to be able to determine the position rather accurately, even though there was no cairn. As we only succeeded in getting two sights at the point, the control of measurements could only be achieved through the levellings, but the computation of the latter showed with sufficient clearness that the measurement at this point had failed so completely that there was only one possible explanation

of the discrepancies in the altitudes computed (95.8 m and 183.6 m) viz. that the telescope had been directed at two different hilltops.

This incident shows how careful one must be, and how necessary it is to control the observations. As the observation journal contains no remarks implying uncertainty, I have consequently in the course of the survey entertained no doubt whatsoever, that from the two stations I have measured at the same point.

The position of the point was determined during the following year, and here it appeared with full certainty that one of the two sights from 1906 had been directed towards quite a different hilltop.

The including of the Observatory in the triangulation network.

In the course of the triangulation of the base net the Observatory had constantly been comprised as "Cairn" from all stations, with the exception of IV. The material collected in this manner for the determination of the position of the Observatory must, however, be considered less valuable, because it had not been possible to point the granite pillar itself, seeing that it did not reach above the side walls of the Observatory. In stead of the pillar I generally pointed the roof of the Observatory; but from the stations I and II I had succeeded in pointing the iron table, which had been cast with the pillar. The black roof was, however, as a rule, difficult to point, and it is also possible that it was not well centred above the axis of the instrument. The errors of centration could, however, easily have been found, but before the computation began, I had made up my mind to condemn all sights at the Observatory (with the exception of sight I—O and II—O), and so the elements of centration of the roof were not measured at all.

Instead of that I determined, by means of two trigonometric station pointings, to connect the Observatory with the base network, as well as directly with the cairns V, VIII and X. The object of the latter station pointing was partly to get a convenient and sure connection of azimuth at the sides of the outer triangles, and partly to facilitate the subsequent computation of the geographical coordinates of the triangulation points.

The trigonometric station pointing is a well-known problem[1]). Its principles will, however, be treated briefly in this place, partly out of regard to the establishment of a practical computation table,

[1]) The below treatment of the problem of the trigonometric station pointing with the computing table belonging to it is a compendium of a guide, published by the General Staff to be used for survey work in Iceland.

partly because this operation, in circumstances like those in Greenland, must occur rather frequently.

Given are the sides a and b. Further in P the angles α and β have been measured. If we knew the angles p and q, all the pieces of the two triangles might be directly determined. That which is given is, however, sufficient to determine p and q, which may be done most easily by finding half of their sum and difference. We have:

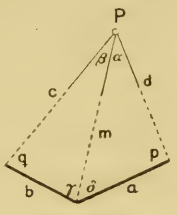


Fig. 30.

$$\alpha+\beta+(\gamma+\delta)+(p+q)=360^\circ,\ {}^1/_2(p+q)=180^\circ\div{}^1/_2(\alpha+\beta+\gamma+\delta)$$

Further $$m=a\frac{\sin p}{\sin\alpha}=b\frac{\sin q}{\sin\beta};\quad \frac{\sin p}{\sin q}=\frac{b\sin\alpha}{a\sin\beta}$$

Now the auxiliary angle u is introduced as determined by $\tan u = \frac{a\sin\beta}{b\sin\alpha}$.

$$\frac{\sin p}{\sin q}=\frac{1}{\tan u}.\quad \text{Hence}\quad \frac{\sin p\div\sin q}{\sin p+\sin q}=\frac{1\div\tan u}{1+\tan u};\ \text{or}$$

$$\frac{2\sin{}^1/_2(p\div q)\cos{}^1/_2(p+q)}{2\sin{}^1/_2(p+q)\cos{}^1/_2(p\div q)}=\frac{\tan{}^1/_2(p\div q)}{\tan{}^1/_2(p+q)}=\tan(45^\circ\div u)$$

$$\tan{}^1/_2(p\div q)=\tan{}^1/_2(p+q)\tan(45^\circ\div u).$$

The correct computation of p and q is controlled by $\tan u=\frac{\sin q}{\sin p}$.

After all the angles of the triangles have been determined, the sides c, d and m are computed by means of the sinus formula. The side m is obtained with control, as it enters into both triangles.

In the latter part of the subsequent table an angle and its opposite side are designated together; thus $p\,m$ indicates angle p as well as the subtending side.

Computation table for the station pointing.

$\gamma+\delta$	log tan u	u .....
$\alpha+\beta$	— tan $(45^\circ\div u)$ ..	$45^\circ\div u$ .....
$\alpha+\beta+\gamma+\delta$	— tan ${}^1/_2(p+q)$..	${}^1/_2(p+q)$ ....
${}^1/_2(\alpha+\beta+\gamma+\delta)$..	— tan ${}^1/_2(p\div q)$..	${}^1/_2(p\div q$ .....
${}^1/_2(p+q)$.....		p .....
		q .....

angles	log sinus	log side	
$\delta\,d$	.....	.....	
$p\,m$	.....	.....	
$\alpha\,a$	.....	....	log $(a:\sin\alpha)$ ....
$\gamma\,c$	.....	.....	
$q\,m$	.....	.....	
$\beta\,b$	.....	.....	log $(b:\sin\beta)$ ....

The table which is filled in, according as the computation progresses, serves to control the computation. If we further desire to control the measurements, we must include a fourth point in the survey (see the example below).

The station pointing demands, as shown by the above, that from P at least three triangulation points are visible; in case one wants to secure a control of the survey, four are required. If still more are visible, one should select the most adaptable ones. In this respect we have to take into consideration:

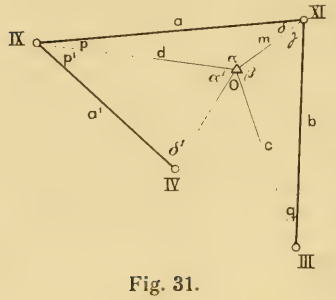


Fig. 31.

1) The sum of the angles $\alpha+\beta+\gamma+\delta$ must not be too near 180° ɔ: P must not be near the circle through the three given points.

2) The three base points must not lie too close together and not at too great a distance from P.

The station pointing of the Observatory (Fig. 31) was carried out with the permanent instrument. The magnitude of the angles measured appears from the computation table.

$\gamma+\delta$	82°25′19″	$\log\tan u$	0.19332	u	57°21′03″
$\alpha+\beta$	242 59 52	$-\tan(45°\div u)$	9.34034 n	$45°\div u$	$\div$ 12 21 03
$\alpha+\beta+\gamma+\delta$	325 25 11	$-\tan\frac{1}{2}(p+q)$	9.49314	$\frac{1}{2}(p+q)$	17 17 24
$\frac{1}{2}(\alpha+\beta+\gamma+\delta)$	162 42 36	$-\tan\frac{1}{2}(p\div q)$	8.83348 n	$\frac{1}{2}(p\div q)$	$\div$ 3 53 56
$\frac{1}{2}(p+q)$	17 17 24			p	13°23′28″
				q	21°11′20″ [1]

		log sin	log side	
δd [1]	31°37′53″	9.71971	3.42299	
pm	13 23 28	9.36473	3.06801	
αa	134 58 39	9.84966	3.55294	3.70328
γc [1]	50 47 27	9.88921	3.39917	
qm	21 11 20	9.55804	3.06800	
βb	108 01 13	9 97816	3.48812	3.50996

1st control of computation: $\gamma+\delta = 82°25'20''$.

2nd control of computation: $\log\tan u = \log\sin q \div \log\sin p = 0.19331$.

3rd control of computation; $\log m = \begin{cases} 3.06801 \\ 3.06800 \end{cases}$

[1] The previously mentioned condemned measurings gave $p=13°23'42''$, $q=21°11'27''$, $\gamma = 50°47'22''$, $\delta = 31°38'05''$. It must here be borne in mind that these values are possibly erroneous in consequence of an eccentric signal.

Control of measurement by means of computation of the side d of the triangle IV—IX—O.

IX.....	47°53′53″	$\log a'$	3.39596
p.....	13 23 28	— cosec α'..	0.03589
p'	34 30 25	— sin δ'....	9.99114
α'	67 01 34	$\log d$...	3.42299 (control!)
δ'	78 28 01		

At the station pointing from the more remote cairns V, VIII and X the angle V—O—VIII was measured at 44°30′05″ and angle V—O—X at 105°47′37″.

The side lengths computed are given in the table below. From the computation appeared ∠ O—VIII—X = 22°49′06″ and ∠ O—VIII—V = 70°49′52″.

The levellings of the triangulation points.

In the measurement of the horizontal angles I had endeavoured to attain as great an accuracy as possible in the given circumstances. My object — to establish a connection with the network of the Germaniaexpedition, the most northerly points of which on Shannon Island and Muschelberg lay more than 150 kilometres in a straight line from Danmarks Havn — demanded the greatest possible accuracy, if the connection was to be of such vital importance to the determination of longitude at Danmarks Havn as I aimed at.

For the determination of the altitudes of mountains, an extreme accuracy in the measurement was of no importance, as our lack of knowledge of the conditions of refraction would always make the results attained rather uncertain. As mentioned above it was, however, for quite different reasons necessary to measure the vertical angles twice. In this manner the accuracy of the measurement of the vertical angles became disproportionately great, and did not correspond to the other circumstances.

The altitude of the telescope above the foot of the cairn was measured at an estimate with a measuring tape, and so also the foot of the cairn itself was nearly always pointed in the course of the levelling. But the "foot of the cairn" was a rather vague conception, which should have referred to the brass bolt in the interior of the cairn, but which came to mean the lower edge of the lowest circle of stones in the cairn, which might, at the same cairn, vary somewhat in its altitude above the level of the sea. It was of great importance that it often turned out to be difficult to point the "foot of the cairn". This was nearly always the case, when we did not have the sky as a background, as well as in a few cases where the cairn

Summary of the lengths of sides in metres.

	log side	side		log side	side		log side	side
I —II	3.16137	1450.0	VI —V	4.25823	18123.0	X —V	4.35406	22597.5
III	3.47151	2961.5	VIII	4.29124	19554.2	VII	4.10542	12747.3
IV	3.22831	1691.6	XII	4.43284	27091.9	VIII	4.26941	18595.6
IX	3.34783	2227.6				IX	3.79079	6177.2
XI	3.13995	1380.2				XI	3.87297	7464.0
O	2.71294	516.3	VII—III	3.71948	5241.8	XII	4.17600	14996.8
			V	3.99928	9983.4	O	3.87474	7494.5
II —I	3.16137	1450.0	VIII	3.95396	8994.1			
III	3.33704	2172.9	IX	3.82219	6640.3	XI —I	3.13995	1380.2
IV	3.31497	2065.2	X	4.10542	12747.3	II	2.95713	906.0
IX	3.55877	3620.5	XI	3.89525	7856.9	III	3.48812	3077.0
XI	2.95713	906.0	XII	3.76144	5773.5	IV	3.42360	2652.2
O	2.98851	973.9	M	3.96786	9286.7	VII	3.89525	7856.9
						IX	3.55294	3572.2
III —I	3.47151	2961.5				X	3.87297	7464.0
II	3.33704	2172.9				O	3.06800	1169.5
IV	3.28365	1921.5	VIII —V	4.06857	11710.5			
VII	3.71948	5241.8	VI	4.29124	19554.2	XII—III	3.70219	5037.2
IX	3.64309	4396.3	VII	3.95396	8994.1	V	3.96791	9287.7
XI	3.48812	3077.0	IX	4.13820	13746.7	VI	4.43284	27091.9
XII	3.70219	5037.2	X	4.26941	18595.6	VII	3.76144	5773.5
O	3.39917	2507.1	XII	4.14631	14005.8	VIII	4.14631	14005.8
			O	4.17899	15100.4	IX	3.96425	9209.8
IV —I	3.22831	1691.6				X	4.17600	14996.8
II	3.31497	2065.2				M	3.74740	5589.9
III	3.28365	1921.5						
IX	3.39596	2488.6	IX —I	3.34783	2227.6	M —V	3.72258	5279.3
XI	3.42360	2652.2	II	3.55877	3620.5	VII	3.96786	9286.7
			III	3.64309	4396.3	XII	3.74740	5589.9
V —VI	4.25823	18123.0	IV	3.39596	2488.6			
VII	3.99928	9983.4	V	4.21534	16418.7	O —I	2.71294	516.3
VIII	4.06857	11710.5	VII	3.82215	6640.3	II	2.98851	973.9
IX	4.21534	16418.7	VIII	4.13820	13746.7	III	3.39917	2507.1
X	4.35406	22597.5	X	3.79079	6177.2	V	4.19812	15780.1
XII	3.96791	9287.7	XI	3.55294	3572.2	VIII	4.17899	15100.4
M	3.72258	5279.3	XII	3.96425	9209.8	IX	3.42299	2648.4
O	4.19812	15780.4	O	3.42299	2648.4	X	3.87474	7494.5
						XI	3.06800	1169.5

stood on a natural plinth, into which it became merged at greater distances.

There can hardly be any doubt that greater accuracy would have been attained by pointing the top of the cairn. The altitude of the latter above the brass bolt was easy to determine by marking off on the bamboo rod, before the latter was erected above the brass bolt, and the determination of the altitude of the telescope in relation to the top of the cairn would only require a levelling of the station

cairn by a cursory sight along the telescope. The distance to the station cairn would then have to be measured with a measuring tape; but this would in any case have to be done out of regard to the computation of centration.

The errors in the levelling, which arose from the fact that the measurements were executed to the foot of the cairn were, however, insignificant compared with those which might be introduced in consequence of variations in the refraction of the atmosphere. This circumstance is dealt with more fully in the section on terrestrial refraction. Here I shall therefore only draw attention to the fact that, when the levelling was performed, I had no knowledge of the natural conditions which give a hint of possible anomalies of the refraction, and that my observation journal consequently contains no remarks which may decide one in estimating discrepancies in the results.

The difference of altitude was computed by the formula

$$H \div H_0 = D \cot z + \frac{1 \div k}{2R} D^2$$

where D is the distance between the two stations, z the zenith distance measured, k the co-efficient of refraction and R the radius of curvature of the normal segment in H_0 through H.

The term $\frac{1 \div k}{2R} D^2$ was taken from the present table, calculated for use in Iceland. R is here computed as a mean value of the curvature of 65°, and in the case of k the value of 0.1306 found by Gauss has been used. In the table D is expressed in kilometres, the other two columns in metres.

The starting points of the trigonometric measuring of altitudes were the termini of the base (stations I and II) the altitudes of which, by means of geometrical levelling, were determined at 14.27 m and 11.26 m.

D	$\frac{1 \div k}{2R} D^2$	Diff.	D	$\frac{1 \div k}{2R} D^2$	Diff.
0.8	0.0				
0.9	0.1				
1	0.1	0.2	21	30.0	2.9
2	0.3	0.3	22	32.9	3.1
3	0.6	0.5	23	36.0	3.2
4	1.1	0.6	24	39.2	3.3
5	1.7	0.8	25	42.5	3.5
6	2.5	0.8	26	46.0	3.6
7	3.3	1.1	27	49.6	3.7
8	4.4	1.1	28	53.3	3.9
9	5.5	1.3	29	57.2	4.0
10	6.8	1.5	30	61.2	4.2
11	8.3	1.5	31	65.4	4.3
12	9.8	1.7	32	69.7	4.4
13	11.5	1.8	33	74.1	4.6
14	13.3	2.0	34	78.7	4.6
15	15.3	2.1	35	83.3	4.9
16	17.4	2.3	36	88.2	4.9
17	19.7	2.4	37	93.1	5.2
18	22.1	2.5	38	98.3	5.2
19	24.6	2.6	39	103.5	5.4
20	27.2	2.8	40	108.9	

In the following the computation of the levelling at Station I is given as an example, whereas in the case of the other stations for which the levelling was computed only the necessary data for the undertaking of the computation have been given, as well as the results of the latter. The zenith distances are given in whole seconds, as found by the computation in the observation journal (see pp. 206—207). It is, however, obvious that whole minutes would in most case have supplied sufficient accuracy.

Station I

Altitude of the telescope above the brass bolt 1.3 m

Cairn	III	IV	IX	XI
z	89°34′38″	90°11′06″	85°52′13″	85°09′58″
log D	3.4715	3.2283	3.3478	3.1400
log cot z	7.8680	7.5091 $_n$	8.8585	8.9272
log D cot z	1.3395	0.7374 $_n$	2.2063	2.0672
D cot z	+ 21.8	− 5.6	+ 160.8	+ 116.8
Altitude of telescope	+ 15.6	+ 15.6	+ 15.6	+ 15.5
Refraction & curvature	+ 0.6	+ 0.2	+ 0.4	+ 0.1
Altitude	38.0	10.2	176.8	132.5

Station II

Altitude of telescope above the brass bolt 1.3 m.

Cairn	III	IV	IX	XI
z	89°20′41″	90°03′48″	87°24′49″	82°28′18″
Altitude	37.7	10.6	177.0	131.4

Station III

Altitude of telescope 38.0 m + 1.4 m = 39.4 m.

Cairn	IV	VII	IX	XI	XII
z	90°51′24″	88°19′16″	88°13′25″	88°16′26″	89°44′52″
Altitude	10.8	194.2	178.5	132.5	63.3

Station IX

Altitude of telescope 177.0 m + 0.8 m = 177.8 m.

Cairn	V	VII	VIII	X	XII
z	90°22′34″	89°52′35″	89°09′07″	87°43′25″	90°44′55″
Altitude	92.5	193.1	394.1	426.1	63.3

Station VII

Altitude of telescope 194.0 m + 1.2 m = 195.2 m.

Cairn	III	V	VIII	IX	X	XII
z	91°44′31″	90°39′31″	88°46′25″	90°11′06″	89°00′49″	91°20′46″
Altitude	37.6	87.2	393.3	176.8	425.7	61.9

Station XII

Altitude of telescope 63.0 m + 1.0 m = 64.0 m.

Cairn	III	V	VI	VII	VIII	IX	X	M
z	90°18′41″	89°52′36″	88°10′30″	88°43′13″	88°41′44″	89°19′32″	88°40′05″	90°25′10″
Refraction & curvature	1.7	5.9	50.0	2.3	13.3	5.8	15.3	2.1
Altitude	38.3	89.9	977.2	195.3	396.2	178.2	428.1	26.1

Station V

Altitude of telescope 88.0 m + 1.4 m = 89.4 m.

Cairn	VI	VII	VIII	IX	X	XII	M
z	87°17′40″	89°26′09″	88°33′08″	89°45′17″	89°14′08″	90°12′09″	90°43′30″
Altitude	968.3	194.5	395.1	178.0	425.7	62.5	24.5

Station VIII

Altitude of telescope 394.0 m + 1.4 m = 395.4 m.

Cairn	V	VI	VII	IX	X	XII
z	91°32′24″	88°23′32″	91°18′39″	90°57′31″	89°58′23″	91°24′36″
Altitude	89.8	970.2	195.1	176.9	427.7	63.9

Station X

Altitude of telescope 426.0 m + 1.3 m = 427.3 m.

Cairn	V	VII	VIII	IX	XI
z	90°56′21″	91°05′25″	90°10′18″	92°20′38″	92°17′23″
Altitude	91.6	195.7	395.2	177.1	132.3

The difference between the altitudes computed for the same point might, as it will appear, sometimes become rather considerable, as far as the points in the base network are concerned up to about 1 metre, as far as the other points are concerned up to about 2 metres; the points V and VI, however, showed differences of as much as 4.5 m and 8.9 m. These deviations, as mentioned above, are mainly due to changing conditions of refraction. When fixing the final values no mean was, therefore, computed; I took it for granted that the levellings on the shortest distances ought to be the best, but otherwise I made allowance for a possible uncertainty of the pointing. An uncertainty of this kind nearly always arose in the case of downward sights, in that the background was then, as a rule, unfavourable.

A striking fact is that all the levellings from Station XII give too high values. This might indicate peculiar conditions of refraction on the day in question.

If we take it for granted that the error dH' on the altitudes computed from a single station is exclusively due to the error dk of the refraction constant, we get, by a simple differentiation of the formula given on p. 227:

$$dH' = \div dk \frac{D^2}{2R}, \text{ or } dk = \div dH' \frac{2R}{D^2}$$

If we further take it for granted that the altitude of the stations given at an estimate in the preceding is correct, as well as that R may be put at 6300 kilometres, we get the following for the computation of dk:

	V	VI	VIII	IX	X
H' (fixed value) ..	88.0	971.0	394.0	177.0	426.0
dH' (kilometre) ..	$\div 0.0019$	$\div 0.0062$	$\div 0.0020$	$\div 0.0012$	$\div 0.0021$
D^2 (kilometre)....	86	738	196	85	225
dk	$+0.3$	$+0.1$	$+0.1$	$+0.2$	$+0.1$

In the case of the points III and VII the computation has not been performed, because the distances to it have been too short to permit of ascribing to the error of the refraction constant a predominant significance as compared with that of the other sources of errors.

From the results it appears that dk may be estimated at $+0.1$ to $+0.3$.

The table on p. 227 is computed by $k = 0.1396$, whereas the value of k corresponding to the conditions during the levelling at Station XII according to the computation just given has been two to four times greater.

The triangulation net at Dove Bugt.

Immediately after his return from the great spring sledge trip in 1907 Bistrup started a careful geographical charting of the regions in and around Dove Bugt. The basis of this survey were the positions of the cairns VI, VII, VIII, IX and X, determined by means of triangulation in the autumn of 1906, the latter making the foundation of a series of trigonometric station pointings round Hvalrosodden (walrus point), Sælsøen (seal lake) and on Teufelkap (Devil's cape).

Thus we are not dealing with a systematic triangulation in Dove Bugt. At the computation, however, it turned out that there was everywhere a control on the measurements except at Station XXIII and so it became possible to compute, in a satisfactory manner, the geographical co-ordinates of Haystack, and to get a means to compare the two determinations of longitude in Danmarks Havn and Germania Harbour, to which comparison, after the problem of the movement of continents has arisen[1]), a certain interest has become attached. In view of this I shall in the following publish the necessary data for the carrying through of the computation of the co-ordinates of Haystack.

[1]) See: Petermanns Geographischen Mitteilungen, April 1912: "Die Entstehung der Kontinente", von Dr. Alfred Wegener, and Samlung Vieweg, Heft 23, 1915: "Die Entstehung der Kontinente und Ozeane", von Dr. Alfred Wegener.

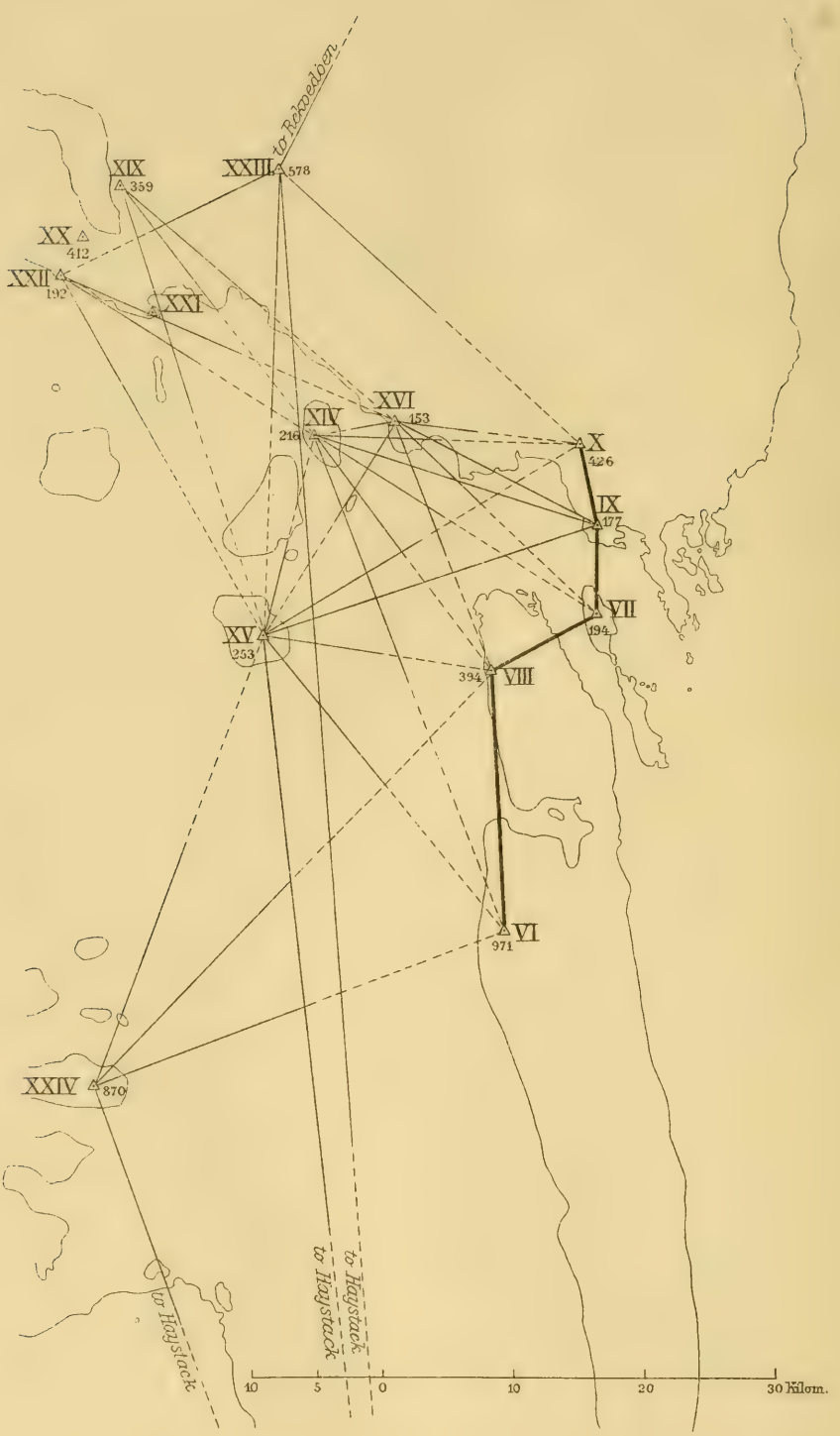


Fig. 32. The triangulation net at Dove Bugt.

A full line indicates that the sight is taken in both directions.
The other lines indicate that the sight is taken **from** the station with which the full part of the line is connected **to** the station with which the dotted part of the line is connected.

Station XIV

Station pointing from X, IX, VIII and VI
$\angle$ X—XIV—VIII = 51°10'00"; $\angle$ VIII—XIV—VI = 16°45'43";
$\angle$ IX—XIV—VIII = 35°34'30".

Station XV

Station pointing from X, IX, VIII and VI
$\angle$ X—XV—VIII = 40°47'08"; $\angle$ VIII—XV—VI = 41°28'11";
$\angle$ IX—XIV—VIII = 28°07'35".

Station XVI

Station pointing from X, IX, VII and VIII
$\angle$ X—XVI—IX = 20°00'15"; $\angle$ IX—XVI—VIII = 41°33'00":
$\angle$ IX—XVI—VII = 16°31'53".

Station XIX

Station pointing from XVI, VIII, XIV and XV
$\angle$ XVI—XIX—VIII = 11°28'04": $\angle$ XVI—XIX—XIV = 11°41'08";
$\angle$ XIV—XIX—XV = 20°09'52".

Station XXI

Station pointing from XIX, XVI, XIV and XV
$\angle$ XIX—XXI—XVI = 126°42'11"; $\angle$ XVI—XXI—XV = 47°33'38";
$\angle$ XIV—XXI—XV = 34°24'53".

Station XXII

Station pointing from XXI, XVI, XIV and XV
$\angle$ XVI—XXII—XIV = 8°57'23"; $\angle$ XXI—XXII—XIV = 8°28'34";
$\angle$ XIV—XXII—XV = 28°38'30".

Station XXIII

Station pointing from X, XV and XXII
$\angle$ X—XXIII—XV = 51°03'56"; $\angle$ XV—XXIII—XXII = 62°16'11"
Besides measured $\angle$ X—XXIII—Haystack = 45°13'34".

Station XXIV

Station pointing from XV, VIII and VI
$\angle$ XV—XXIV—VIII = 23°38'05": $\angle$ VIII—XXIV—VI = 24°44'53"
Controlled by means of the azimuth of the sun (see "The geogr. survey of Dove Bugt")
Besides measured $\angle$ VIII—XXIV—Haystack = 118°57'55".

In the table given below the computed lengths of sides are given. In order that one may form an idea of the accuracy attained, I have given the single results, which have appeared from the computation.

Under "established values" are given partly results which appear direct from computations, partly results arrived at by means of an estimate of the values computed, regard being had to certain instructive remarks in the observation journal, as well as to the more or less advantageous shape of the triangles.

The triangulation net in Dove Bugt.
Length of sides in metres.

Side	Established values	Computed values	Side	Established values	Computed values
XIV —VI	40115	40115.1—40112.6	**XIX** —VIII	46132	46132—46070
—VIII	22645	22645.6—22643.0	—XIV	23511	23512—23425
—IX	22347		—XV	35202	
—X	20084		—XVI	26834	26834—26814
—XV	15431		—XXI	9964	
—XVI	6098				
—XIX	23511				
—XXI	14993		**XXI** —VIII	37296	
—XXII	21996		—XIV	14993	14976—14996—15008
			—XV	25266	25266—25266
XV —VI	28985	28984.8—28986.6	—XVI	19655	19642—19657—19656
—VIII	17992	17991.0—17992.1	—XIX	9964	9957—9971
—IX	26563		—XXII	7112	
—X	28034				
—XIV	15431				
—XVI	18827		**XXII** —XIV	21996	22001—21990
—XIX	35202		—XV	30574	30574—30569
—XXI	25266		—XVI	26778	
—XXII	30574		—XXI	7112	
XXIII	34472		—XXIII	17980	
XXIV	36861				
			XXIII —X	29846	
XVI —VII	20935		—XV	34472	
—VIII	20557		—XXII	17980	
—IX	17137	17136.7—17136.0	—XXIV	70476	
—X	14156	14155.8—14155.4			
—XIV	6098				
XV	18827		**XXIV** —VI	33465	
XIX	26834		—VIII	44033	
—XXI	19655		—XV	36861	
XXII	26778		—XXIII	70476	

It will appear that the uncertainties at the stations XIV, XV and XVI, which are directly connected with the triangulation stations of 1906, are inconsiderable. The greatest deviation between the computed values of the side lengths amounts to 2.6 m.

In the case of stations XIX and XXI the deviations, on the other hand, are considerable. As far as Station XIX is concerned this is due to the fact that the control had to be looked for through a triangle of a most unfavourable shape. As far as the computation of the connection with the triangulation of the Germaniaexpedition is concerned, the uncertainty at these two stations is of no importance, as the connection is completely independent of them.

At Station XXII the uncertainty is also rather considerable; the

greatest difference between two values of the same side is here 11 m i. e. about $\frac{1}{2000}$ of the length of the side. Station XXIII being determined by X, XV and XXII, the uncertainty of XXII comes to influence the position of Station XXIII, and thus again the position of Haystack. As the triangles through which Station XXIII is determined have a particularly favourable shape, the uncertainty of XXII hardly plays any great part.

Station XXIV is very favourably determined by VI, VIII and XV; the uncertainty of this station must be trifling. Besides the station is to a certain extent controlled by means of a determination of azimuth (see "The geogr. survey of Dove Bugt").

With the exeption of the stations XIX and XXI, which, as mentioned above, are of no importance as regards the connection wtth Haystack, one may take it for granted that the error of the position of the stations in Dove Bugt, in relation to the Observatory at Danmarks Havn, does not exceed a few metres.

Geographical co-ordinates of the triangulation stations.

According to the hypothesis advanced in 1912 by Dr. Alfred Wegener as to the movement of continents, Greenland was presumed to slide in a westerly direction. Wegener makes an attempt to compute the average yearly movement for a period of 50,000 to 100,000 years, and thus arrives at a yearly rate of 14—28 m. This hypothesis, so extremely far-reaching in its consequences, has lent a certain interest to the work of the Danmark-Ekspedition in the direction of determinations of longitude and triangulation, in that it has become possible, through the triangulation, to compare the results of the determination of longitude of the Germaniaexpedition in 1869—70 with that of the Danmark-Ekspedition in 1907.

The determination of the geographical co-ordinates of the Observatory at Danmarks Havn are mentioned in detail in the section "The Work in the Observatory". The result of the determination became:

$\varphi = 76°46'14''.6 \pm 0''.4.$
$l = 1^h15^m50^s.3 \pm 2^s.4 = 18°42'34'' \pm 36''$ west of Grw.
Azimuth of Cairn V from the Observatory $A_{0-V} = 358°17'40''.5.$

The computation of the differences of latitude and longitude in a network of triangulation is a problem treated in every geodetic compendium. The formulæ which have been used in the computation are the following:

$$\varphi_0 = \varphi \div s$$
$$\varphi_1 = \varphi_0 \div \sigma$$
$$l_1 = l + \theta$$
$$z' = z \div 3\gamma \div t + 180°$$
$$s = [1]_m K \cos(z \div 2\gamma)$$
$$v = [2]_0 K \sin(z \div \gamma)$$
$$\gamma = \frac{1}{6\omega} sv;\ \log \frac{1}{6\omega} = 3.9074 \div 10$$
$$\theta_0 = v \sec \varphi_0$$
$$t_0 = v \tan \varphi_0$$
$$\sigma_0 = [3]_0 v t_0$$
$$\log \theta = \log \theta_0 \div 4c t^2{}_0$$
$$\log t = \log t_0 \div 4c t^2{}_0 \div 2c v^2$$
$$\log c = 3.9298 \div 10$$
$$[1]_m = \frac{\omega}{M_m};\ [2]_0 = \frac{\omega}{N_0};\ [3]_0 = \frac{N_0}{2\omega M_0}$$

φ and l are the given latitude and longitude of the starting point A.
z is the given azimuth of the point B in A.
φ_1 and l_1 are the required latitude and longitude of point B.
z' is the required azimuth of A in B.
φ_0 is an approximate value of φ_1.
$[1]_m$ is taken from a table for argument $\frac{\varphi + \varphi_1}{2}$.
M_m is the radius of curvature of the meridian in the latitude $\frac{\varphi + \varphi_1}{2}$.
ω is the radius expressed in seconds.
$[2]_0$ is taken from a table for the argument φ.
N_0 is the radius of curvature in the normal segment to the meridian in the starting point.
$[3]_0$ is taken from a table for the argument φ_0.
K is the triangle side AB.
γ is a spherical excess (positive when z is situated in the first and third quadrant; negative when z is situated in the second and fourth quadrant.)
θ_0, t_0 and σ_0 are approximate values of θ, t and σ.

The value given for $\log c$ expresses all the c-corrections in units of the sixth decimal place.

The computation from the above-mentioned formulæ becomes slightly indirect, in that the determination of γ and $[1]_m$ demand a preliminary computation of s and v; but the final computation is restricted to a supplement of the preliminary one. As the accuracy with which the triangulation of the Danmark-Ekspedition was performed would make it absurd, on any point, to reckon with smaller units than tenths of seconds, the excess γ only comes to play a part in the very largest triangles. The quantity $[1]_m$ may everywhere, with

sufficient accuracy, be taken at once from the map at an estimate of $\frac{\varphi + \varphi_1}{2}$. In by far the greatest number of cases the indirect computation is consequently dropped altogether.

As there were no tables of the quantitues [1], [2] and [3] north of 72° it was necessary first to compute the auxiliary table below of the quantities mentioned, where M and N are expressed in metres.

φ	$\log[1] = \log \frac{\omega}{M}$	$\log[2] = \log \frac{\omega}{N}$	$\log[3] = \log \frac{N}{2\omega M}$
74°30′	8.508668	8.508459	4.38472
75°00′	8.508648	8.508452	4.38472
75°30′	8.508629	8.508445	4.38471
76°00′	8.508610	8.508438	4.38470
76°30′	8.508592	8.508431	4.38468
77°00′	5.508574	8.508425	4.38467

As the geodetists of the Germaniaexpedition had not themselves computed the geographical co-ordinates of their triangulation stations, I have also had to perform this computation in the case of the stations on which the position of Haystack was dependent. The necessary data are to be found in "Die zweite deutsche Nordpolfahrt, Bd. II, Wissenschaftliche Ergebnisse". The results are presented in the table given below, and are here given in tenths of seconds. This accuracy, which in this case corresponds to a table of 5 decimals, is naturally only an accuracy of computation. which aims at avoiding an accumulation of errors in calculation.

The stations are given in the order of succession in which they were computed.

The Danmark-Ekspedition.

Station	φ	l	Azimuth of	
Observatory, O	76°46′14″.6	18°42′34″	V	358°17′40″.5
			VIII	42°47′45″.5
			X	148°35′21″.5
V	76°37′45″.8	18°41′28″.5	O	178°18′44″
			VI	34°57′03″
			VIII	113°38′41″
VIII	76°40′16″.1	19°06′28″.9	O	222°24′29″
			V	293°14′21″
			VI	358°35′02″
			X	199°35′24″.5
			XV	99°34′06″
			XXIV	44°20′41″

The Danmark-Ekspedition (continued).

Station	φ	l	Azimuth of
X	76°49'40".7	18°51'46".7	O ..... 328°26'24" VIII ..... 19°44'43" XV ..... 59°01'25" XXIII ..... 132°03'25"
VI	76°29'45".6	19°05'22".1	V ..... 214°33'49" VIII ..... 178°36'07" XXIV ..... 69°06'39"
XV	76°41'49".1	19°47'55".3	VIII ..... 278°53'47" X ..... 238°06'47" XXIII ..... 182°12'43"
XXIII	77°00'20".1	19°44'44".3	X ..... 311°11'50" XV ..... 2°15'49"
XXIV	76°23'10".5	20°16'45".6	VI ..... 247°57'15" VIII ..... 223°12'20"

The Germaniaexpedition.

Station	φ	l	Azimuth of
Observatory [1])	74°32'15".5	18°49'25".5	5 ..... 184°05'39".6 Hasenberg ..... 125°12'17".4
5	74°34'32".1	18°48'48".8	Observatory ..... 4°06'15".6 Hasenberg ..... 75°57'47".5 8 ..... 328°47'25".6
Hasenberg	74°33'54".3	18°58'12".5	Observatory ..... 305°03'49".4 5 ..... 255°48'44".1 8 ..... 275°19'39".7 Keferstein Berg ... 186°13'31".3
8	73°33'37".0	18°46'43".4	5 ..... 148°49'26".5 Hasenberg ..... 95°30'43".8 Klein Pendulum .. 218°57'17".0 Hühnerberg ..... 68°35'48".6
Keferstein Berg	74°47'48".3	18°56'36".3	Hasenberg ..... 6°15'04".1 8 ..... 327°49'59".1 Klein Pendulum .. 251°39'21".6
Klein Pendulum	74°40'28".8	18°25'40".9	8 ..... 39°17'34".3 Hühnerberg ..... 54°43'26".7 Keferstein Berg ... 72°09'10".8 Kap Bremen..... 128°04'04".8

[1]) As to fuller particulars of the uncertainty of the co-ordinates of the Observatory of the Germaniaexpedition see pp. 252—255.

The Germaniaexpedition (continued).

Station	φ	l	Azimuth of	
Hühnenberg	74°30′04″.5	19°20′07″.2	8	248°03′37″.3
			Klein Pendulum	233°51′00″.7
			Kap Bremen	339°49′01″.3
Kap Bremen	74°59′58″.6	20°03′32″.7	Klein Pendulum	306°29′37″.5
			Hühnerberg	339°44′01″.3
			Muschelberg	198°38′58″.9
Muschelberg	75°11′22″.4	19°48′30″	Kap Bremen	18°53′32″.1

The position of Haystack.

Haystack is not marked off by means of a cairn, but as indicated by the name, given to it by Clavering in 1823, the top is shaped like a regular cone, so that the sighting point. the top of the mountain,

Haystack seen from the North.

becomes sufficiently clearly defined. The mountain, the altitude of which is 310 m is contiguous to the high table land at Kap Seebach, by means of a small isthmus, which only rises a few metres above the level of the sea. Seen from a distance Haystack gives the impression of being an island close outside the coast, and so Haystack was also drawn in Clavering's map. As there are no other prominent points or islands on or near this part of the coast, the probability was excluded of sighting at a wrong point during the survey.

On the sketch, Fig. 32, of the triangulation net in Dove Bugt are shown three sights at Haystack. Of these the sight from Station XV is, however, so uncertain, that it can only be used for a rather rough control of the two other ones.

The fact is that when in the summer of 1907 I returned from the sledge trip to Peary Land, Bistrup had commenced the survey of Dove Bugt, and had measured from Station XV. From here he

had, in the course of the geographical sketching survey, pointed Haystack at a single sight, the direction of which was read off in whole minutes. The possibility that the position of the instrument at Station XV during the geographical sketching survey may have been eccentric cannot be dismissed. In this manner there may, in the direction measured, have been introduced an error of several minutes, which as far as the geographical sketching survey in general is concerned, is quite immaterial, but which in this special case, where the controlling computation is to be carried through a triangle with an angle of a few degrees, makes the computation very uncertain. After I had pointed out the importance of determining the position of Haystack with the greatest possible accuracy, Bistrup included it as an object in the triangulation from the stations XXIII and XXIV. The directions from these two stations at Haystack were thereby established by means of three complete sets.

The computation of the position of Haystack had to be carried through the triangles XXIII—XV—XXIV and XXIII—Haystack—XXIV.

The triangles are shaped thus

△ XXIII—XV—XXIV	△ XXIII—Haystack—XXIV
∠ XXIII ..... 9°12′51″	∠ XXIII ..... 15°03′13″
∠ XV ..... 162°10′26″	∠ Haystack .. 13°44′04″
∠ XXIV ..... 8°36′43″	∠ XXIV ..... 151°12′43″
log XXIII—XXIV = 4.84874	log XXIII—Haystack = 5.15519
	log XXIV—Haystack = 4.88703.

Both of these triangles have a rather awkward shape. This, however, only influences the lengths of the sides XXIII—Haystack and XXIV—Haystack, but not the azimuth of these sides, which is determined by the angles measured X—XXIII—Haystack = 45°13′34″ and VI—XXIV—Haystack = 94°13′02″ in connection with the azimuths of the sides X—XXIII and VI—XXIV. As the azimuth of XXIII—Haystack and XXIV—Haystack are 356°25′24″ and 342°10′17″ respectively, a small error in the lengths of the sides may constitute a very noticeable error in the latitude of Haystack, but will, on the other hand, be without practical importance whatever as regards the determination of the longitude.

As the result of the computation we get:

Haystack 1907	φ	= 75°43′38″
	l	= 19°25′18″
	Azimuth Haystack—XXIII	176°44′14″
	Azimuth Haystack—XXIV	163°00′09″

The above-mentioned unreliable sight from XV to Haystack gives in the case of Haystack $\varphi = 75°43'03''$ and $l = 19°25'17''$. As was to be expected, there is a very considerable difference between the two values of the latitudes, whereas the longitudes are very nearly the same.

In the map of the Germaniaexpedition PAYER makes use of three different signatures for his observation stations. The first sort he calls "Astron. trig. Standorte", and hereby he indicates, as far as I can see, only the triangulation station determined by the geodetists BÖRGEN and COPELAND in their attempt of gradimetry. These stations are determined by a complete measurement in thirty-six sets. The other sort he calls "Trigonometrische Fixpunkte", the third sort "Graphische Punkte".

On PAYER's map Haystack is designated as "Trigonometrische Fixpunkt".

Beyond the map PAYER has, unfortunately, published nothing about his observations. By a lucky chance Koldewey, however, published the bearings of three of PAYER's sights at Haystack.

During the sledge trip in 1870 to Germania Land Koldewey determined the co-ordinates of Haystack at $\varphi = 75°44'.5$, $l = 19°10'$ [1]). As in particular the longitude differs considerably from the one indicated on PAYER's map, Koldewey takes occasion to remark in a footnote: "Die Länge von Haystack ist auf der PAYER'schen Karte..... zu 19°23' angegeben. Es sind für die Construction folgende Winkelmessungen benutzt worden.

$\angle$ Tellplatte—Kap Bremen—Haystack ..... 72°51'.7
$\angle$ Tellplatte—Muschelberg—Haystack ..... 130°33'
$\angle$ Kl. Pendulum—Keferstein Berg—Haystack 77°14'.

Of the three angles given Tellplatte—Muschelberg—Haystack must necessarily be encumbered with a very serious error (130°33' is possibly a printers' error for 103°33'). This direction must thus be condemned, and the co-ordinates of Haystack must consequently be computed from Keferstein Berg and Kap Bremen. But before this a computation must be made of the triangle Keferstein Berg—Klein Pendulum—Kap Bremen. This triangle looks as follows:

$\angle$ Kap Bremen—Keferstein Berg—Kl. Pendulum.. 109°28'15''
$\angle$ Keferstein Berg—Kl. Pendulum—Kap Bremen.. 55°54'54''
$\angle$ Kl. Pendulum—Kap Bremen—Keferstein Berg.. 14°36'51''
log (Kap Bremen—Keferstein Berg) = 4.720858.

[1]) Die zweite deutsche Nordpolfahrt, Bd. II, p. 756.

After this comes the computation of the triangle Kap Bremen—Haystack—Keferstein Berg. In this triangle the seconds are calculation figures, in that the angles at Keferstein Berg and Haystack may be encumbered with errors of as much as half a minute.

The triangle looks as follows:

$$\begin{aligned}
\angle \text{ Haystack—Kap Bremen—Keferstein Berg} &= 128°08'56'' \\
\angle \text{ Kap Bremen—Keferstein Berg—Haystack} &= 32°14'15'' \\
\angle \text{ Keferstein Berg—Haystack—Kap Bremen} &= 19°36'49'' \\
\log(\text{Kap Bremen—Haystack}) &= 4.92202 \\
\log(\text{Keferstein Berg—Haystack}) &= 5.09059 \\
\text{Azimuth Kap Bremen—Haystack} &= 192°57'32'' \\
\text{Azimuth Keferstein Berg—Haystack} &= 174°25'22''
\end{aligned}$$

$$\text{Haystack}_{1870} \begin{cases} \varphi = 75°43'42'' \\ l = 19°22'42''. \end{cases}$$

As will appear the computation of the longitude of Haystack in 1870 agrees with Payer's value given by Koldewey, $l = 19°23'$.

The drift of North Greenland in a westerly direction.

The earlier computed values of 1870 and 1907 of the latitude of Haystack harmonize better than might be expected; the difference is four seconds or about 120 metres. On the other hand the longitudes harmonize badly, in that the determination of longitude of 1907 indicates the position of Haystack as 2'36'' or about 1190 metres[1]) more westerly than the determination of 1870.

The question is now: May this discrepancy be explained in a reasonable manner through the uncertainty with which the measurements are encumbered.

The uncertainty arises from the following sources of error:

1) The astronomic determination of longitude.
2) The astronomic determination of azimuth.
3) The base measurement.
4) The triangulation.

[1]) Wegener gives in Peterm. Mitt. 1912 the difference as 590 m, which information he got from me. The longitude of the observatory in Danmarks Havn was then not finally computed, and the co-ordinates of the triangulation stations were not determined. In order to answer Wegener's question as to the position of Haystack, I undertook at the time a rough computation of the triangulation net, and knowing the use which the information was to be put to, I was extremely careful not to get the position of Haystack too westerly.

As far as the Danmark-Ekspedition is concerned the matter stands nearly as follows:

ad 1. The mean error of the astronomic determination of longitude is 36″ or very nearly 256 m (see p. 129).

ad 2. The two values of the azimuth Observatory—Cairn V deviate from each other by 2″. It will of course not do to base a mean error determination on this. On the other hand one may say that this discrepancy in regard to the division of the circle, reading methods, placing on the granite pillar etc., corresponds to what might a priori be expected, as well as that a difference of 10″ would have been surprisingly great. (For further particulars see under Determinations of Azimuth pp. 101—103). If we put the actual error of the azimuth of Cairn V from the Observatory at 20″, we must be said to have reached the limit of what is practically possible. An error of twenty seconds in this place will, however, only entail an error of about 12 m on the longitude of Haystack.

ad 3. The mean error of the base measurement is 1 : 10000 of the base. If the base is presupposed to be erroneous to this extent, the longitude of Haystack will in this manner undergo a change of about 2 m.

ad 4. It is more difficult to form an estimate of the influence of the many small partial errors in the triangulation. The influence is twofold, in that it expresses itself as an error partly in the lengths of the sides of the triangles, partly in the azimuths of the latter. By comparing the computed lengths of the sides of the triangles, one will, however, get the impression that the error in the sides of triangles of 1906 cannot reasonably exceed 1 : 10000 of the lengths of the sides. In the case of the sides of the triangles at the stations XV, XXIII and XXIV, which are of any importance to the position of Haystack, the uncertainty, it is true, is somewhat greater, but may hardly, with any reason, be estimated at more than 1 : 5000 of the lengths of the sides. The lengths of the sides XXIII—Haystack and XXIV—Haystack are uncertain, but it must be borne in mind, partly that errors in the lengths of these sides have practically no influence on the longitude of Haystack, partly that these lengths of sides to a certain extent are controlled, because the latitudes computed for Haystack from north and south harmonize as well as one might a priori be entitled to expect.

After this one may take it for granted that the uncertainty of the lengths of the triangle sides does not practically influence the longitude of Haystack. On the other hand, this hardly holds good of the uncertainty with which the azimuths of the sights at Haystack are encumbered.

In the preceding I have under the computation of the triangulation network of 1906 given the error of the sum of the angles in the case of twenty-five triangles. Upon an average this error is 13″; all the errors in the sum of the angles vary between + 27″ and ÷ 31″, and they are rather evenly distributed on both sides of zero. After this one must admit that some few angles may have an error of as much as $^1/_2$ minute.

Now it must be borne in mind that the two stations from which the position of Haystack is directly determined have an extremely simple connection with the Observatory

O—X, X—XXIII and
O—VIII, VIII—XXIV.

The co-ordinates of the two stations, XXIII and XXIV, are computed through these sides with a controlling computation respectively through

O—VIII, VIII—XV, XV—XXIII and
O—V, V—VI, VI—XXIV.

The possibility of a considerable accumulation of errors is thus excluded. If we presuppose that the azimuth XXIII—Haystack has an error of 2′, we are at the limit of what is practically possible; but hereby there would, on the longitude of Haystack, arise no greater error than 80—90 metres (the side XXIII—Haystack is about 143000 m). That an error of this kind does not exist is shown by the controlling sight XV—Haystack as well as by the azimuth determined at Station XXIV by means of an observation of the sun (as to this see the section "The geogr. survey of Dove Bugt".

It appears from the preceding that the sources of error given are neither singly nor collectively sufficient to suggest an explanation of the difference of about 1190 m which exists between the positions of Haystack, as determined by the Danmark-Ekspedition and the Germaniaexpedition. The only source of error, which in this connection plays any part, is the astronomical determination of longitude. But in order to explain the deviation through the error of the longitude of the Observatory we must put the actual error of the astronomical determination of longitude at four to five times the mean error, which is perfectly absurd.

We have finally to make an examination of the observations of the Germaniaexpedition.

The base measurement and triangulation of the Germaniexpedition with appurtenant astronomical determinations have been performed by the trained astronomers and geodetists C. Börgen and

R. Copeland. The object was a thorough examination in all details as to whether a measurement of the length of the meridian degree in North Greenland was practicable. The equipment and the arrangement of the work corresponded thereto. As to the performing of the work and the subsequent treatment of the material, Börgen and Copeland write [1]):

"Wir haben sowohl bei der Beobachtung selbst, als nachher bei der Berechnung der Messungen, obwohl wir uns nie der Illusion hingaben, dass unsere Arbeit eine definitive sein könne, doch stets so gehandelt als ob sie es wäre, denn gerade dadurch hofften wir manche Erfahrung zu machen, die einer wirklichen Gradmessung zu Gute kommen würde, die uns aber bei weniger sorgfältiger Ausführung entgangen wäre."

Thus we are here dealing with a work which aimed at a far greater accuracy than the corresponding work performed by the Danmark-Ekspedition.

A base of 709.1509 metres was measured by means of a base apparatus consisting of wooden rods, glass wedges and trestles. The measuring of the angles was performed by means of a universal instrument, the micrometer-microscopes of this permitting to estimate the readings in 0″.4.

The observations also generally show an inner harmony, which altogether excludes errors of such a magnitude as to become of importance in the present research.

The longitude of the Observatory in Germania Harbour was determined by means of seventeen moon culminations and four occultations of stars. The result of this was

in the case of the moon culminations $l = 1^h15^m16^s.9 \pm 1^s.1$ (probable error),

in the case of the star occultations $l = 1^h15^m18^s.3 \pm 1^s.1$ (probable error).

In spite of the same probable error a somewhat different weight is ascribed to the two values, i.e. 3 and 4 respectively, and so the final result becomes:

$$l = 1^h15^m17^s.7 \pm 1^s = 18°49'25''.5 \pm 15'' \text{ (mean error)}.$$

Converted into metres the mean error here becomes 124 m, in other words very nearly half as great as at Danmarks Havn.

Latitude and azimuth were determined with a corresponding degree of accuracy. During the triangulation the angles were measured in thirty-six sets. A general equalization was performed,

[1]) Die zweite deutsche Nordpolfahrt, Bd. II, p. 764.

from which it appeared that the corrections of the directions never reached 6″.

A considerable uncertainty, however, is implied by the circumstance that the greater part of the base was only measured once. This appears very strongly by a comparison between the latitude of the most northerly station, Muschelberg, computed by means of the triangulation net and the latitude observed in the same place.

The latitude of Muschelberg is determined by means of observations of the zenith distance of the sun near its upper culmination at 75°11′29″.3 ± 0″.7 (probable error). This gives a difference of 6″.9 from the value computed through the triangulation net, given on p. 237. As a starting value for the computation of the latitude of the triangulation stations, we used for the observation in Germania Harbour $\varphi = 74°32'15''.5$, which is the most probable value of all the determinations of latitude in the Observatory. If when fixing the latitude of the Observatory one had only used the zenith distance observations of the sun performed in that place at the upper culmination, one would from the Observatory have got $\varphi = 74°32'16''.7 \pm 0''.6$ (probable error). In this manner the difference between the computed and the observed latitude would, as far as Muschelberg is concerned, become 5″.7 or about 177 metres[1]).

Börgen and Copeland have attempted to explain part of the very marked difference between the two values of the latitude of Muschelberg through the deviations of the plumb. Under certain plausible, but of course doubtful presumptions they compute the deviations of the plumb, as far as the Observatory and Muschelberg are concerned, at 2″.45 towards north and 1″.98 towards south respectively, and then they write:

"Wenn daher die so gefundenen Ablenkungen der Lothlinie richtig sind, so würde der Breitenunterschied um 4″.43 zu gross beobachtet werden sein, und die Abweichung des geodätisch und des astronomisch gefundenen Abstand der Parallele würde von 182.198 auf 44.882 Meter herabgebracht werden, eine Grösse, welche man wohl den Fehlern der Messung zuschreiben kann."

The difference of 44.882 may be explained in a plausible manner through the uncertainty of the two determinations of latitude in the Observatory and at Muschelberg. In particular, the possibility is not excluded that the determination of latitude in the Observatory may be encumbered with a systematic error of a few seconds (see pp. 252—255). As, however, the base has only been measured once, the possibility of a gross error is not excluded. In order to be on the safe side, I

[1]) Börgen and Copeland give the difference at about 182 metres.

will then assume that the whole deviation of 5″.7 of the two values of the latitude of Muschelberg is due to an error in the base, which must then be supposed to have been measured too short by 1.8 metres or about $^1/_{400}$ of its own length. The result of this would, however, only be that Haystack was shifted about 5″ or about 40 metres towards the west.

There still remains a valuation of the uncertainty with which the azimuths from Keferstein Berg and Kap Bremen at Haystack may be encumbered. As already mentioned by Koldewey, the former of these directions is given in whole minutes and may thus, if for that reason only, suffer from an error of $^1/_2$ minute. If, however, one maintains that the sight is possibly encumbered with errors of eccentricity, the error on the sight may be at most 3 to 4 minutes, in which manner the longitude of Haystack will undergo a change of about 100 metres.

If one wishes to explain the discrepancy of the position of Haystack through an error of the sight Keferstein Berg—Haystack, this difference must be put at nearly one degree. In this manner the longitudes might be brought to harmonize, but at the same time discrepancies would arise between the latitudes of about $1^1/_2$ minutes, so that by this means nothing is gained. The same applies to the sight Kap Bremen—Haystack. In case the difference of longitude at Haystack has to be explained as a consequence of an error in the triangle Kap Bremen—Haystack—Keferstein Berg, one is forced to the supposition, as regards both of the azimuths Kap Bremen—Haystack and Keferstein Berg—Haystack, that they have an error of about $1^1/_2$ degrees towards east. A supposition of this kind is, however, quite absurd.

From the foregoing it will appear that the greatest uncertainty in the determination of the longitude of Haystack from Germania Harbour, also in this place, is due to the observation of longitude in the Observatory. It is true that, under certain rather improbable hypotheses the possibility of two other considerable sources of error has been demonstrated; but even when we have had recourse to these, we have not succeeded in finding a plausible explanation of the difference between the two determinations of the longitude of Haystack, neither through the work of the Danmark-Ekspedition, nor through that of the Germaniaexpedition. One might suppose the observations to be encumbered by certain constant errors, which would cause the expressions of accuracy to become incorrect. As sources of such errors may be mentioned deviations of the plumb and errors in the refraction tables. Errors of this kind are pointed out by the Germaniaexpedition, as well as by the Danmark-Ekspe-

dition, but they are so small that they are of no importance as to the problem before us.

Consequently I see no other possibility than to seek the explanation in another direction than through errors in the observations, and, as far as I know, nothing is here forthcoming except the hypothesis put forth by Dr. Wegener as regards the drift of Greenland towards the west. Dr. Wegener estimates the period that has elapsed, since Greenland broke loose from Norway, at 50 000 to 100 000 years. The distance between Greenland and Norway he puts at 1400 kilometres, and in this manner he arrives at a average yearly drift of 14—28 metres, which computation rests on a supposition so uncertain that there is nothing to prevent the movement from falling even rather far outside the limits found through the estimate.

If one takes it for granted that Greenland at 74°—77° latitude has really drifted 1190 metres towards west within the period 1870—1907, the consequence is an average yearly drift within the period mentioned of 32 metres. The hypothesis of Wegener thus receives a not inconsiderable support, but can of course not be looked upon as proved by this means. It will, therefore, be of great interest, if other criteria of the drift are found.

In his oft-mentioned treatise Wegener has made an attempt to provide such a criterion, by means of the determination of longitude of Sabine in 1823. In this manner he arrives at the result that the drift towards west within the period 1823—1870 should amount to 260 m. This computation rests on a very insecure foundation; but in case one wishes to carry it through, the main source of the valuation of the site of Sabine's Observatory must be the indication of the latter on the map drawn by Clavering in 1823. As Wegener has not had access to this map, I will in this place take up the matter for renewed investigation.

What makes the investigation uncertain is the fact that one does not know the site of the Observatory of Sabine, but is reduced to conjectures.

On his map Clavering has marked off the meridian through the Observatory of Sabine, and on the map itself he has expressly given it as "Meridian of the Observatory 18°50′00″ west of Greenwich"[1]); but he has not in any other way indicated the site of the Observatory

[1]) Chart of the East Coast of Greenland between the latitudes of 72° and 76° from observations on H. M. Ship Griper, Douglas Charles Clavering Esq. F. R. S., Commander, 1823. The map is published for the first time in copperplate print in Edward Sabine's work: An account of experiments to determine the figure of the earth by means of the pendulum vibrating seconds in different latitudes. London, 1825.

on the map. As we know, from the description of SABINE, quoted below, that it lay directly on the coast, the place on the map thus becomes determined by the point of intersection between the coast line and the meridian of the Observatory. CLAVERING's map shows, as appears from the accompanying reproduction of a part of it (Fig. 33) with all the clearness that one can wish for that SABINE's Observatory was situated on the outer (western) coast of the small peninsula bounding Germania Harbour towards the west — the "Sternwartenhalbinsel" of the Germaniaexpedition. Further it seems rather clear that the Observatory must be looked for in the most northerly part of the peninsula.

Fig. 33.

PAYER, whose map (Fig. 34) of the Pendulum Islands in 1:100000 gives the impression of being very carefully prepared, has drawn an elbow in the coastline in nearly the place where CLAVERING's meridian of the Observatory intersects the coast, but he has, as will appear from the accompanying reproduction, placed SABINE's observatory nearly 270 m southeast of the elbow[1]).

The following will in the main show the state of the case:

In the official report of the Germaniaexpedition we find[2]):

"Es war uns an und für sich schon sehr interessant, irgendwelche Andeutungen von dem vor 46 Jahren hier stattgehabten Besuche unserer Vorgänger, der englischen Expedition unter SABINE-CLAVERING, aufzufindcn; den Astronomen aber musste noch ganz besonders darum zu thun sein, nach Vorschrift der Instruction die Stelle zu entdecken, wo SABINE damals sein Observatorium errichtet hatte, aber vergeblich forschten wir an allen geeigneten Orten. Die Aufgabe war auch eine sehr schwierige, da SABINE, wie wir wussten, ein hölzernes Observatorium mitgebracht hatte, und die an Bord befindliche Literatur uns keinerlei topographischen Anhalt bot. Erst nach unserer Rückkehr wurden wir bei einer Einsicht des Original-

[1]) Originalkarte. Pendulum Inseln von JULIUS PAYER, Massstab 1:100000. Die zweite deutsche Nordpolfahrt, Leipzig 1873—74, Bd. I.

[2]) Die zweite deutsche Nordpolfahrt, Bd. I, p. 597.

berichtes über jene Reise direct darauf hingewiesen, dass das Gebäude nahe bei den erstbeschriebenen Eskimohütten gestanden hat".

The Eskimaux huts mentioned lie on the outer side of the "Sternwartenhalbinsel". A more accurate determination of the place I have not been able to find.

The passage in the original report of Sabine — the above-

Fig. 34.

mentioned "Account of experiments" — to which allusions have been made runs as follows:

"The harbour in which the Griper remained from the 15th to the 31st of August was formed by the channel[1]) which separates the mainland from an island[2]) in which the experiments were made, and was secured from the access of heavy ice from the ocean, by a smaller island[3]) situated in the mid-channel at the entrance ... The

[1]) Clavering Strædet (straits).
[2]) Sabine Ø (island).
[3]) Hvalros Ø (walrus island).

anchorage was abreast of a plain of considerable extent, on the inner or south westernmost of the two largest islands; the plain consisted of the debris of a sandstone rock, and was generally swampy; but a perfectly dry spot, which had been the site of an Esquimaux village, was found for the pendulums on the shore close to the anchorage ... The height of the pendulums above the sea was ascertained by direct measurement, to be thirty-one feet and a half."

On, or at any rate in the neighbourhood of the ruins of the Esquimaux houses we must look for SABINE's Observatory, but unfortunately PAYER has not marked off the ruins of the houses on his map. As the latter, however, are situated within a kilometre from the wintering place of Germania we may suppose that PAYER has had a tolerably clear understanding of its site, when, after the return of the expedition, he marked off the site of SABINE's Observatory on the map.

In doing this, however, he must have encountered a difficulty, which it has been impossible for him to overlook, that is, that the determination of longitude of SABINE could not in this manner be brought into harmony with that of the Germaniaexpedition.

Also BÖRGEN and COPELAND must necessarily have realised this, and it is rather peculiar that they do not mention the fact; but they may have rested content with the thought that after all one did not know, where SABINE's Observatory had been, and that the matter was consequently not worth mentioning. PAYER, on the other hand, had to surmount the difficulty, and to assist him in that he had the determination of latitude of SABINE. The latitude of the Observatory in Germania Harbour is, when only the observations of the sun are taken into account, determined at 74°32′16″.7, whilst SABINE, likewise by means of observations of the sun, has determined the latitude of his Observatory at 74°32′18″.6. On PAYER's map, however, SABINE's Observatory lies about 120 metres or about 4″ more northerly than the Observatory in Germania Harbour, which in so far is striking, as the discrepancy between the longitudes of the two observatories would have become smaller, in case PAYER had marked off SABINE's Observatory accurately from the latitude given by the latter or a still more southerly latitude. He may, of course, have been of opinion that he ought to pay some attention to CLAVERING's map, or to the site of the ruins of the houses, and on the other hand it may be some smaller inaccuracy we are dealing with.

A somewhat exhaustive comparison between the latitudes of the two observatories is not without interest. At the comparison we can, as already observed, only take count of the observations of the sun, because SABINE has nothing else to go on. The basis of the compari-

son is that the computations are performed according to the same presumptions as regard the refraction.

Sabine used the refraction tables of Thomas Young in the Nautical Almanac for 1822, whereas Börgen and Copeland used Bessel's refraction tables, though they have multiplied the Besslian refraction by 0.952[1]). A re-computation of the refraction of Sabine's observations according to Börgen and Copeland's manner of proceeding, gives the following results:

Sabines computation						Re-computation		
Date 1823	Apparent zenitdist.	B. (English inches)	Temp. (Fahrenh.)	Refr. N. A. 1822	φ	Refr. Germ.-exp.	φ'	Remarks
21. Aug...	62°12′32″	29.90	39	1′51″.7	74°32′18″.4	1′47″.0	74°32′13″.7	Sextant and artificial horizon
22. — ..	62°32′24″	29.95	39	1′53″.5	74°32′16″.6	1′48″.7	74°32′11″.8	Repeating Reflecting Circle and mercurial horizon
23. — ..	62°53′30″	29.90	37.5	1′55″.3	74°32′20″.0	1′50″.4	74°32′15″.1	
25. — ..	63°33′58″	29.72	38	1′57″.8	74°32′19″.9	1′52″.9	74°32′15″.0	Repeating Circle
26. — ..	63°54′56″	29.74	44	1′58″.4	74°32′17″.9	1′53″.3	74°32′12″.8	
				Mean...	74°32′18″.6		74°32′13″.7	

According to this Sabine's Observatory should thus be situated 3″ more southerly than the Observatory in Germania Harbour, in which manner it would, judging by the course of the coastline on Payer's map, lie in the meridian 18°50′00″ west of Greenwich, and so complete harmony would have been established between Sabine's determination of longitude and that of the Germaniaexpedition, while, on the other hand, there would undoubtedly arise a serious discrepancy as compared with Clavering's map.

There can be no doubt that Börgen and Copeland have performed the same re-computation of Sabine's observations as shown above. Such complete agreement between their determination of longitude and that of Sabine would have been a great triumph for them. Astronomers by profession[2]) they could not help seeing the importance of the various ways of computing the refraction, so much the less as they had themselves worked on the problem of refraction, and on the basis of their own observations had taken the opportunity

[1]) As to fuller particulars of this, see under "Astronomical Refraction", pp. 136—146.

[2]) Börgen, who had studied astronomy and geodesy in Copenhagen, Kiel and Göttingen, was in 1866 appointed assistant at the Observatory of Göttingen. He died a director of the Observatory of Wilhelmshaven. Copeland, who had received his scientific education in England, in 1865—1867 studied astronomy in Göttingen, and afterwards became an assistant at the Observatory in that town. He died a director of the Edinburgh Observatory.

to compute a correction factor for the Besslian refraction. But they knew that an agreement of this kind would be illusory, because it could neither be brought to harmonize with CLAVERING's map nor with the site of the ruins of houses which they must necessarily know. (We will later on recur to the doubtful justice of the above attempt to determine the mutual position of SABINE's Observatory in 1823 and of the Observatory of the Germaniaexpedition in 1870 by re-computing the observations of SABINE).

As mentioned above, the determination of longitude of the Germaniaexpedition have a mean error of about 124 metres. SABINE's determination of longitude is the result of

12 moon culminations (transit instrument) . . .	18°49′42″	west of Grw.
110 moon distances (sextant, artificial horizon) .	18°50′12″.6	— —
Mean . . .	18°49′57″.3	

SABINE's determination of longitude may be supposed to suffer from a similar uncertainty as that of the Germaniaexpedition.

Building upon the indication of PAYER as to the site of SABINE's Observatory, WEGENER has computed the discrepancy between the two determinations of longitude at 260 metres; but BÖRGEN and COPELAND cannot have believed in PAYER's indication, for in that case they would themselves have drawn attention to the discrepancy which might at a pinch be explained through the uncertainty of the determinations of longitude. BÖRGEN and COPELAND have naturally kept silent as to this matter, because they could not descry any possibility of a reasonable explanation, and because they would not cast unwarranted doubt on SABINE's observations, or those they had made themselves.

How thoroughly the members of the Germaniaexpedition have discussed this matter in all its bearings, and how eagerly they have looked for possibilities of reconciling conflicting points appears clearly from the passage quoted above from the official report of the Germaniaexpedition as well as from the slight alteration in SABINE's "a spot which had been the site of an Esquimaux village was found for the pendulums", which became "dass das Gebäude nahe bei den Eskimohütten gestanden hat". The word "nahe" which is unwarranted in SABINE, and which opens the door to unlimited possibilities of placing the site of SABINE's Observatory is hardly a casual alteration of the text. Very illustrative in this respect is also the account in "Die zweite deutsche Nordpolfahrt", Bd. I, p. 597, of the importance assigned to the find of half of the bottom of a beer

bottle, and of the discussion which ensued among the members of the expedition in connection with this piece of glass.

The above research must give one the impression that it seems hopeless to try to find support for the hypothesis of the drift of Greenland towards the west in the determinations of longitude undertaken by Sabine and the Germaniaexpedition, as long as the site of the ruins of the houses and so also the position of Sabine's Observatory in relation to that of the Germaniaexpedition are unknown. The difficulty which we have hitherto not been able to surmount is that Clavering in his map has clearly indicated the site of Sabine's Observatory in a place which according to Payer's map must be about 260 metres or about 8″.4 *farther north* than the Observatory of the Germaniaexpedition. In this place, where the projecting elbow in the coastline is, the ruins of the houses should be found. This also seems the more probable explanation, as the Esquimaux, when the waves flung themselves against the peninsula from the open sea, only in the little bight north of the above-mentioned elbow might find favourable landing conditions for their kayaks.

I have on a previous occasion gone into the possibility that the determination of latitude made by Sabine might be encumbered by a systematic error, but the research did not lead to the desired harmony with Clavering's map; on the contrary it made the discrepancy greater. There is, however, also a possibility that the systematic error is to be looked for in the observation of latitude of the Germaniaexpedition.

Accurate observations of the sun are a difficult thing in arctic regions, because the sun's rays here have an extremely powerful effect and easily induce systematic errors. (For fuller particulars as to this, see "The Work in the Observatory" pp. 92—93). The use of an observatory may further occasion an error which is caused by the special refraction of the meridian aperture; the latter may, in an arctic observatory, easily amount to a couple of seconds, particularly in the summer, where the observatory is brought up to a very high temperature owing to the influence of radiation.

The walls of the Observatory of the Germaniaexpedition were built of natural stone[1]); the roof which was made of boards and canvas could not be lifted off, so that the circulation of air only took place through the door and the 1/2 metre broad meridian aperture. There has, however, probably also been an aperture for observations in the prime vertical. That the conditions of a great

[1]) Die zweite deutsche Nordpolfahrt, Bd. I, pp. 434 and 435.

refraction of the meridian aperture have been particularly favourable seems evident[1]).

In case one wishes to make sure against the effect of the refraction of the meridian aperture one must measure the temperature of the air immediately in front of the objective of the telescope, which is not so very easy with an ordinary thermometer. On the Danmark-Ekspedition I made use of Assmann's aspiration psychrometer for this purpose. The Germaniaexpedition, however, did not bring aspirators for the thermometers, and it has consequently hardly been possible to read off, with any certainty, the temperature in front of the objective. However, as Börgen and Copeland do not at all mention this difficulty, it seems probable that they have simply read off the temperature in the thermometer locker, which was to be found directly on the north wall of the Observatory.

There are in the series of observations of the Germaniaexpedition several circumstances showing that Börgen and Copeland have not been able to avoid rather considerable systematic errors. Whether the refraction of the meridian aperture is one of these it is, at the present moment, not possible to decide, among other things because the individual temperature readings under the meteorological observations have not been published. This much, however, is clear, that the discrepancy in the observations of the Germaniaexpedition cannot be explained solely on the hypothesis of a strong refraction of the meridian aperture (The determination of latitude at Muschelberg, where the observations were performed in the open air, gives with the upper culmination of the sun $\varphi = 75°11'32''.9$ whereas the lower culmination gives $\varphi = 75°11'16''.0$ — Besslian refraction).

Börgen and Copeland interpreted the discrepancy in a way which led to the computation of the above-mentioned factor of correction, 0.952, of the Besslian refraction. A fuller treatment of the problem as to whether a factor of correction of this kind is fully justifiable will be found in the section "Astronomical Refraction" pp. 136—146. Here I shall only remark that the observations of the Danmark-Ekspedition may hardly be said to offer any support for the justification of a factor of this kind, and also that the observations of the Germaniaexpedition at least contain one circumstance which speaks against applying the factor of correction.

On August 5th, 6th and 8th, 1869 Börgen and Copeland per-

[1]) In the Observatory at Danmarks Havn throughout the summer I lifted the whole roof off, so that the Observatory only consisted of four whitewashed walls. Nevertheless the temperature of the air in front of the objective of the telescope might be more than one degree higher than that of the air outside the Observatory.

formed a series of determinations of latitude by means of the sun, at a point which lay 5″.65 more northerly than the pillar in the Observatory [1]). These observations gave, computed under the application of the above-mentioned factor of correction, for the Observatory the latitude of $\varphi = 74°32'05''.5$. If, however, the observations are computed without applying the factor of correction, one gets for the Observatory $\varphi = 74°32'10''.1$, in which manner the agreement with the result of the determinations of latitude performed in the Observatory by means of Polaris, $\varphi = 74°32'13''.7$ (Besslian refraction) becomes much better.

Sabine has undoubtedly performed his determinations of latitude in the open air, as his Observatory was taken up by the pendulums. Besides the use of an artificial horizon in a movable observatory is, as a rule, too inconvenient.

By a comparison between the determinations of latitude made by Sabine and those of the Germaniaexpedition one ought, according to what has been stated above, only lo take open-air observations into account, and as a measure of precaution it would be most correct from Sabine's observations only to take those which, like those of the Germaniaexpedition, are performed by means of a theodolite. In this manner we get:

Sabine's Observatory ..... $\varphi = 74°32'20''.1$ [2])
The Observatory of the Germaniaexpedition $\varphi = 74°32'10''.1$.

According to this the site of Sabine's Observatory would thus be about 10″ farther north than that of the Germaniaexpedition.

In this manner, under reasonable supposition, the necessary agreement with Clavering's map has been brought about. As the difference of latitude, as already observed, should be 8″.4, it will appear that, practically speaking, an equally good agreement would have been obtained for the latitude of the Germaniaexpedition, if one had used that determined by Börgen and Copeland, solely by means of the Polaris $\varphi = 74°32'13''.7$ (Besslian refraction).

Taking it for granted that Börgen and Copeland computed their observations with an incorrect value of the refraction, the question arises whether this circumstance has not caused a greater systematic error in the longitude. This is, however, not a likely supposition. Börgen and Copeland have determined the longitude of the Observatory, partly by means of observations of the moon partly by

[1]) See note to the determinations of latitude in "Die zweite deutsche Nordpolfahrt", Bd. II, p. 725.

[2]) Mean of 74°32'20″.7 and 74°32'19″.5. The computation is performed with Besslian refraction, without applying a factor of correction.

occultations of stars. The error in the determination of longitude arises — apart from the general uncertainty of the co-ordinates of the moon — almost exclusively from the error of the determination of time, and here one may, with great certainty, take it for granted that the two astronomers have arranged their determinations in such a manner that an error in refraction could not come to play any part worth mentioning. However, as the determinations of time of the Germaniaexpedition have not been published, it is no longer possible to verify this circumstance.

If one absolutely wants to maintain that CLAVERING cannot have marked off the site of SABINE's Observatory in a wrong place — and as often mentioned this seems to me the most natural conclusion to adopt — one arrives by means of PAYER's map, whether starting from the one or the other hypothesis as to the difference of latitude between the two observatories, at the result that the drift in a westerly direction in the period 1823—1870 was about 420 metres or about 9 metres a year. For the entire period 1833—1907 the average yearly movement towards west will be 19 metres.

Have we now, by means of the two determinations of longitude on Sabine Island, found the support for the supposition concerning the drifting of Greenland which we sought?

The question may, I suppose, be answered in the affirmative. It cannot be denied that the whole of the research is encumbered with a very serious uncertainty, and that the two mean values of the yearly drift, 9 m within the period 1823—1870 and 32 m within the period 1870—1907, do not harmonize very well. It must, however, not be overlooked that we have no knowledge of the forces that cause the presumed drift. It would, I suppose, in reality seem more natural if the drift did not show itself an even movement, but subject to considerable variations at different periods[1]).

The uncertainty of the mutual position of the two observatories on Sabine Island might in the main be got rid of by a short visit to the place itself. If the visit were extended over a fortnight, it

[1]) According to the hypothesis of WEGENER the rift in the Atlantic Ocean has opened from the south, and only during the glacial age has it caused Greenland to break away from Norway, which theory corresponds with a series of well-known geological as well as phyto- and zoogeographical circumstances.

WEGENER consequently thinks that the drift in more southern parts cannot be supposed to proceed with the same rapidity as in the case of Greenland. To support his theories he quotes the result of the three telegraphic determinations of longitude between Greenwich and Cambridge (North America) that is

1866	difference	of	longitude	$4^h 44^m 30^s.89$
1870	—	-	—	$4^h 44^m 31^s.065$
1892	—	-	—	$4^h 44^m 31^s.12$.

might furthermore be possible to determine the influence on the latitude and azimuth exercised by systematic errors of the observations performed in the Observatory by the Germaniaexpedition. Further, one might use the opportunity to mark off the site of the Observatory of the Germaniaexpedition and the cairn on Hvalrosøen or that on Hasenberg in a satisfactory manner. Such a marking off would be of great interest in the case of future determinations of the geographical co-ordinates of the Observatory.

Sabine Island or the neighbouring part of Greenland is very often visited by whalers as well as by tourist steamers. A visit extending over a fortnight would thus hardly entail insurmountable difficulties in the way of expense.

During my stay at Sabine Island in the month of November 1907 the walls of the Observatory of the Germaniaexpedition were to a certain extent standing. The sandstone pillar on which the instrument had been placed was still in its place, but it was loose and could easily be removed. The cairn on the northern point of Hvalrosøen had, at any rate, not collapsed altogether. The cairn on Hasenberg which I visited in July 1900, was at that period nearly intact.

In the Observatory a granite pillar ought to be made fast to the ground by means of cement. With a corresponding solidity the site of the cairns on Hvalrosøen or on Hasenberg ought to be marked off.

Greenwich and Cambridge are situated at 51°28′.6 and 42°22′.8 N. latitude respectively. If after this one computes the drift towards the west, one gets:

From 1866—1870 in all about 55 metres: yearly average about 14 metres.
— 1870—1892 in all about 17 metres: yearly average about 1 metre.

Note that the discrepancies between the three telegraphic determinations of longitude cannot very well be explained as a result of the uncertainty of the determinations.

CHAPTER III.

The Geographical Survey.

Introductory Remarks. Instruments.

In a cursory, forced survey of an unknown stretch of land, one must start by understanding that every direct connection by sights from the one station to the preceding or succeeding one is going to fail. It must thus as a matter of fact be possible to map out every single station independently of the others, i. e. at every single station one ought to perform the necessary astronomical observations for the determination of longitude, latitude and azimuth.

On the other hand one ought, to the fullest extent of one's powers, to aim at establishing a connection between the stations, by means of terrestrial observations; the more successful the connection of this kind is, i. e. the more the connection between the stations assumes the character of a triangulation net, the more solid will be the framework constituting the basis of the whole survey.

One condition necessary in order to obtain a direct connection between the stations is ample time, so that one may stop in every place where a halt is necessary, out of regard to the connection, and there to perform the necessary ascents of mountains, in order to get a general view of the surroundings. During forced sledge trips, however, one never has sufficient time, and one only stops, when one's strength is spent, and arduous ascents of mountains are almost invariably out of the question. One is forced to choose one's station in places of no special prominence on the sea-ice or in the immediate neighbourhood of the coast, and the connection between the stations must, as a rule. be restricted to the pointing from each station of a few prominent peaks that become visible during a period of travel covering several days, and which thus in a way become the fixed points of the framework. Under these conditions one must pay particular attention to the astronomical determinations to avoid running the risk of the map becoming a more or less arbitrary mosaic of fragments, and not a connected whole.

The cartographical equipment of a sledge party generally consisted of:

1 small universal instrument with compass and tripod,
1 pocket chronometer and 1 or 2 ordinary watches,
2 swing thermometers as well as during the coldest period one alcohol thermometer,
1 prism binocle,
1 hodometer,
1 drawing portfolio with chequered paper,
Pocket book and drawing materials,
Almanac and logarithm tables.

The travelling universal instrument has been mentioned on an earlier occasion (see p. 204). Here I shall only add that the instrument is arranged in such a manner that it may, in an emergency, be fastened upon the box, so as to be used without applying the tripod, which measure became of great importance, as I myself lost my tripod in a snowstorm on Peary Land. The compass could be fitted on the instrument, in which manner it became possible conveniently to perform cursory determinations of the magnetic declination, simultaneously with the determinations of azimuth. The idea was that in dull weather one might substitute an azimuth by the compass for an azimuth of the sun; the compass, however, became of no practical importance to the survey, because an overcast sky together with bright weather was a great rarity.

Also the pocket-chronometers have been mentioned on earlier occasions. As I had been taught by my experience of the first autumn that they could not stand the cold, because the oil froze, we later on carried them on our bare breasts in a chamois leather or flannel bag. They were only taken out for quite short periods to compare the watches and be wound up in the evening, as well as now and then for watch comparisons before and after an observation.

Before leaving home I had thought that a sledge party would on an average break two swing thermometers per month, and we had consequently laid in a stock of a hundred. However, we soon learned to make solid cases for these instruments, consisting of tubes from boiler piping, and so we broke comparatively few. On the return of the expedition we had still more than sixty thermometers left.

The alcohol thermometers were superfluous for cartographic use; at temperatures below the freezing point of the mercury one ought, as a general rule, not to make astronomical observations.

Souchier's distance meter — of which the expedition carried two — was only used by HAGEN and myself. It can easily be carried in the pocket, cannot get out of order and does not cost much, but measuring with it requires some practice and cannot be performed under all circumstances.

Souchier's distance meter consists of a glass prism of the shape indicated in Fig. 35.

For protection the prism is enclosed in a covering of celluloid or ebonite, except the pieces $A\,F$ and $D\,C\,H$. Above the latter spot a slide is placed, so that when sighting through $D\,C$ one may cover $C\,H$ and vice versa.

Suppose the point at which the distance is to be measured to be G; the point is supposed to be so far off that the two rays of light Gm and Gn may be considered parallel. If one looks through the plane $C\,H$, G will be visible in the direction G_1, which deviates 90° from the original one; if on the other hand one looks through the plane $D\,C$, G will be visible in the direction G_2, which with the direction at G_1 constitutes an angle of about 1°10′.

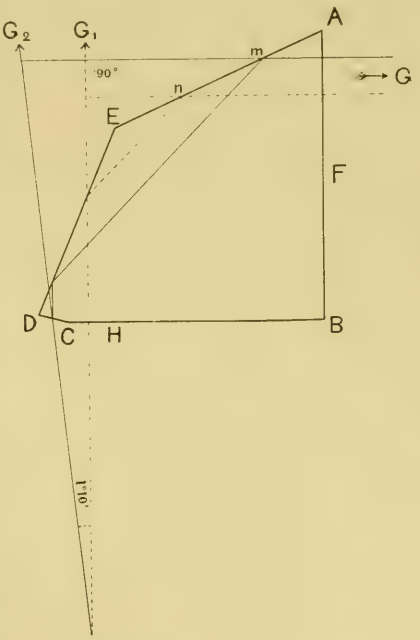


Fig. 35. Souchier's distance meter.

The principle underlying the use of the instrument is as follows: One sights through the plane $D\,C$ towards G, which is supposed to be visible nearly in the direction towards S (Fig. 36). One shifts backwards and forwards and laterally, so long until one finds in the terrain a remote, sharply defined point S, the picture of which coincides with the picture of G. The standing place A is marked off with a stick, and the observer moves backwards in the prolongation of $S\,A$, until through the plane $C\,H$ he sees G in the direction $B\,A\,S$.

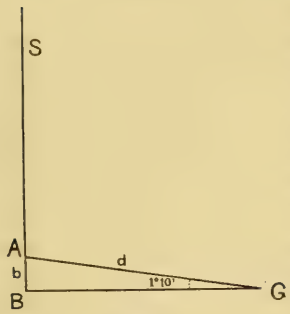


Fig. 36.

Thus one gets the distance looked for:

$$d = \frac{b}{\sin 1°10'} = 50\,b.$$

The base line *b* is measured by pacing or with the measuring tape.

The most difficult feature of the survey and that which involves the greatest loss of time is the finding of a suitable point of direction and getting the latter in the direction of the sight; this difficulty, however, partly disappears, according as one becomes trained in the use of the instrument. It is of the greatest importance to select a remote point of direction. In this manner the error committed through not being quite accurately adjusted in the line between the first station and the point of direction is diminished.

The circumstance that the instrument may be used for the

Fig. 37. Dog sledge with hodometer.

pegging out of a right angle may, by the way, come in useful during surveys.

The hodometer is a wheel, the revolutions of which are automatically indicated on a register.

Our hodometers were bicycle wheels without rubber tyres. The circumference was two metres. The wheel was put in a fork placed behind the sledge.

As a cartographical instrument the hodometer was of no great assistance, the sledging being too uneven for that. In pack-ice where one had to wriggle a good deal, the hodometer, of course, indicated a distance which was far too great for cartographical purposes, whereas on glare ice it often indicated too small a distance. On an even, hard snow plane it was, however, rather reliable.

The greatest use of the hodometer is, however, to be looked for in a different field. During the long and fatiguing marches it has a stimulating effect to see how the little register adds kilometre to kilometre. Many a time when fatigue and hunger have come very near to making me give orders to camp, the hodometer has roused me to reneved efforts, by showing me that another hour would round off the kilometres up to thirty.

The Astronomical Determinations.

The spring journeys are of the greatest importance, as far as surveys are concerned, in that it is then light throughout the twenty-four hours, so that one may continue one's work independently of the time of the day, until one's labours at the station are completed. By far the greater part of the astronomical determinations therefore become observations of the sun; only in the autumn can there now and then be occasion to have recourse to the stars.

As mentioned above, the conditions on long sledge trips as a rule make it necessary for the cartographer to reduce the ideal claims he has cherished in respect of his work, and look for modest comfort in the fact that "half a loaf is better than no bread". One must guard against the danger of this, in particular as far as the astronomical determinations are concerned.

When after a fatiguing march one camps at 3 o'clock in the morning, no small amount of energy is required to tackle the observations so as to be able to finish the latter with a determination for time at about 6 o'clock; at seven one has, at an estimate, computed the observations and marked off the results on the map, and then at last one may go to one's badly-needed rest in the sleeping bag, not to give way to fatigue and enjoy a deep sleep, but to force oneself to wake up at eleven in order to make ready in good time for the noon latitude. One is far too apt to let things slide, hoping to awake at the right moment or comforting oneself with the thought that on an emergency a latitude can be taken outside the meridian. But when, after one's return, one sets to work on the often extremely troublesome and irritating puzzle of bringing a reasonable harmony between the observations from the various stations, bitter repentance ensues for every proof of weakness, and decided distrust is manifested towards every observation for which the most favourable conditions possible have not been provided.

During the sledge trips part of the observations must often be roughly computed, in order that a map may be sketched on the spot. It will often be possible to content oneself with treating the observations of latitude and azimuth, whereas the determinations of

time can wait till one's return. The means necessary for a rough computation of the observations are extremely simple: A refraction table, a small azimuth table and a few pages of a nautical almanac. Besides I brought a four-placed logarithm table, but on the Danmark-Ekspedition I had no occasion to use it on sledge trips[1]).

The refraction table and the azimuth table were always kept on the first two pages of my pocket book; they would, for instance, look as follows:

Refraction table[2]).

Mean refraction		Temperature correction		Barometric correction	
Apparent zenith dist.	Mean refraction	Temperature centigrade	Factor	Barometer mean	Factor
85°	9′.9	÷ 30	1.17	780	1.03
84.5	9.2	÷ 28	1.16	770	1.01
84	8.5	÷ 26	1.15	760	1.00
83.5	7.9	÷ 24	1.14	750	0.99
83	7.4	÷ 22	1.13	740	0.97
82.5	7.0	÷ 20	1.13	730	0.96
82	6.6	÷ 18	1.12	720	0.95
81.5	6.2	÷ 16	1.11	710	0.93
81	5.9	÷ 14	1.10	700	0.92
80.5	5.6	÷ 12	1.09	690	0.91
80	5.3	÷ 10	1.08	680	0.90
79	4.9	÷ 8	1.07	670	0.88
78	4.5	÷ 6	1.06	660	0.87
77	4.1	÷ 4	1.06	650	0.86
76	3.8	÷ 2	1.05	640	0.84
75	3.6	0	1.04	630	0.83
74	3.3	+ 2	1.03	620	0.82
73	3.1	+ 4	1.02	610	0.80
72	3.0	+ 6	1.02	600	0.79
71	2.8	+ 8	1.01	590	0.78
70	2.6	+ 10	1.00	580	0.76
65	2.1	+ 12	0.99	570	0.75
60	1.7	+ 14	0.99	560	0.74
55	1.4	+ 16	0.98	550	0.72
50	1.2			540	0.71
40	0.8			530	0.70
30	0.6			520	0.68
20	0.4			510	0.67
10	0.2			500	0.66

Ex.: $z_a = 78°43'.3$; $t = \div 22.4$; $b = 627.3$;

$r = 4'.8 \times 1.13 \times 0.83 = 4'.5$.

[1]) On the voyage across Greenland in 1913 it was, on the other hand, necessary to compute all the determinations of time while travelling.

[2]) The members of the sledge parties of the Danmark-Ekspedition only carried tables of the mean refraction, in other words, without tables of correction for temperature and atmospheric pressure. On several occasions the table proved insufficient. The table reproduced in this place I used on the voyage across Greenland in 1913.

Azimuth table[1]).

t		0m	4m	8m	12m	16m	20m	24m	28m	32m	36m
		0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0h00m	0°		242	543	719	844	940	019	086	143	194
0h40m	10°	240	281	318	352	384	413	440	466	490	513
1h20m	20°	534	554	574	592	609	626	642	657	672	686
2h00m	30°	699	712	724	736	748	758	769	779	789	799
2h40m	40°	808	817	826	834	842	849	857	864	871	878
3h20m	50°	884	890	897	902	908	913	919	923	928	933
4h00m	60°	937	942	946	950	954	957	961	964	967	970
4h40m	70°	973	976	978	981	983	985	987	989	990	992
5h20m	80°	993	995	996	997	998	999	999	999	999	999

Formula: $\sin a = \frac{\sin t \cos \delta}{\cos h_i} = \frac{\sin t \sin (90 \div \delta)}{\sin z}$

Example: $t = 2^h32^m$, $\delta = 10°$, $z = 45°$, NW-ly

$\log \sin t$ 789

$\log \sin (90 \div \delta)$.. 993

$\log \operatorname{cosec} z$ 151

933 = 59°

$a = N\ 59°\ W.$

Determinations of latitude.

When commencing the observations at a station, one lacks, as a rule, a more accurate knowledge both of latitude and of time.

It must therefore be possible to compute the determinations of latitude without a knowledge of the time, as also the determinations of time must, to as great an extent as possible, be made independent of an accurate knowledge of the latitude.

As a matter of principle the latitude ought therefore to be taken in the meridian; the hour of noon is of course preferable, out of regard to the smaller zenith distance and resulting smaller uncertainty of the refraction, but midnight can also be used. If, by a mere exception, one is forced to attempt a latitude outside the meridian, the observation must be supported by means of a determination of time near the prime vertical and taken from the same station; otherwise one would generally lack the knowledge of the time which is necessary in order to be able to compute the latitude.

In case the determination of latitude is to take place without friction, the knowledge of the clock time of the culmination within

[1]) The table which is a table of log sin from degree to degree is an imitation of an English table of azimuth. The omitted characteristic is 9, exeept in the five underlined logarithms, where it is 8.

about ten minutes is necessary; but this knowledge will be easily procurable by means of an examination of the determination of latitude immediately preceding. This little calculation occurs so frequently that it is of practical value to know how much 10 kilometres in east-west means in minutes.

If we put 30 kilometres = 16 minutes we get on 80°

$$10 \text{ km} = 10 \times \frac{16}{30} \times \frac{1}{\cos 80°} \times \frac{1}{15} \text{ minutes (of time)}$$

$$= \text{about } 10 \times \frac{1}{2} \times 6^{1}) \times \frac{1}{15} = \text{about } 2 \text{ minutes.}$$

Let us presume that the sun during the preceding observation culminated at about 11^h55^m and that since by the hodometer we have travelled 76 km towards WNW on about 80° latitude. The equation of time and the clock correction to Grw. is supposed to be unchanged in minutes from the last observation.

The distance towards west then becomes $76 \cos 22^1/_2°$. As $\cos x$ may now approximately be put $= 1 \div \frac{x^2}{2}$, $76 \cos 22^1/_2$ becomes nearly $76 \div 76 \times \left(\frac{22}{57}\right)^2 \times \frac{1}{2} = 76 \div 76 \times \frac{1}{2.5^2} \times \frac{1}{2} = 76 \div 76 \times \frac{1}{12} =$ about 70 km = about 14 minutes (of time).

According to this the sun should culminate at about 11^h49^m.

The little estimate of $\cos 22^1/_2°$ is after all superfluous. The error in the distance of the hodometer may easily become as great as 10 kilometres. In case the hodometer indicates 76, and presuming one has followed a normally sinuous route, one might fittingly have estimated the distance towards west at 60 kilometres, the clock time of the culmination thus becoming about 11^h47^m.

After this one ought to be ready to commence the observations at 11^h30^m, especially if one has no assistant to record and look after the watch during the observation. The unpacking and setting up of the instrument generally takes five minutes; but one ought to reckon with a quarter of an hour. Not only is it good for the instrument to stand for about ten minutes in the sun, before the observation commences (as to this see under observations of the sun in the permanent Observatory, p. 93) but it also frequently happens that it takes longer to adjust the instrument, for instance because the bubble of the level turns out not to be of proper size.

If one can get an assistant to record and read off the watch, it is of course a help; but at determinations of latitude one can very

[1]) $\frac{1}{\cos 80°} = \frac{1}{\sin 10°} =$ about $1 : \frac{10°}{57°} =$ about $1 : \frac{1}{6} =$ about 6.
On this occasion as well as at several other estimates of a similar kind, a certain intimate knowledge of trigonometric functions is of practical importance, as one cannot always lay one's hand on an engineer's scale or a logarithm table.

well see to everything oneself. It is in such cases advisable to place the leather case of the instrument between the legs of the tripod, to place the watch here and read it off immediately after pointing the sun. It is of no importance that in this manner one will always come to read off the watch a few seconds too late; besides one can very nearly determine, by way of experiments, the loss of time in reading off the watch and reduce the clock time accordingly.

Should one not be possessed of a watch, one may, in lieu of it, use the horizontal circle for this purpose[1]).

Whether at determinations of latitude one points the upper or the lower limb of the sun is, as a rule, immaterial; only, as long as one is not very expert, one ought to be content to use the one limb.

In the following I am going to give a few examples of what the instrument can do under the difficult arctic conditions.

Latitude, noon 6/V 1907 (observed by Koch without an assistant). ☉; b = 770 mm; t = ÷ 14° C; velocity of the wind 6 m; light snow drift. Instrument placed on snow-cowered sea-ice 5 to 10 km south of Kap Ejler Rasmussen. l = about 1^h30^m w. of Grw. One division of the level = 20″.

Telescope left					Telescope right				
Clock time	Vernier		Level		Clock time	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$11^h34^m00^s$	293°38′.8	39′.1	12.5	7.3	$11^h36^m25^s$	66°21′.6	22′.6	3.6	8.8
39 00	39.1	39.5	12.0	6.8	40 50	21.2	22.2	6.3	11.7
42 55	39.2	39.6	11.5	6.2	44 35	21.1	22.1	3.7	8.8
46 45	39.2	39.6	11.5	6.3	48 45	21.0	22.0	3.0	8.3
50 45	39.2	39.5	12.0	6.7	53 10	21.1	22.1	3.0	8.2
55 00	39.1	39.4	11.6	6.2	57 00	21.2	22.2	3.0	8.2

For the rough computation only the fourth pair is used, which judging by the readings is lying nearest to the culmination.

Telesc. left.... 360° ÷ 293°39′.4	= 66°20′.6
Telesc. right	66°21′.5
Mean	66°21′.1
Level +	0.5
Refr. +	2.5
$\rho + \pi$[2]) ÷	16.0
δ +	16°18.1
φ =	82°26′.2

[1]) See A. Marcuse: Handbuch der geographischen Ortsbestimmung, Braunschweig, 1905, p. 235.

[2]) $\rho + \pi$ = semi-diameter + parallax.
δ = declination.

An estimate of this kind, which takes about ten minutes, is often only a few tenths of a minute removed from the result, which one gets by a complete computation of the series of observations.

A glance at the series of observations shows that the first pair of observations is comparatively far removed from the meridian and that the level in the course of the second pair of observations, telescope right, has shown a rather problematical reading. It is quite a normal occurrence for the level not to be willing to be adjusted at the beginning of a series of observations, and there might consequently be good sense in condemning the first two pairs. In this place, however, we are going, for the sake of perfection, to treat the whole series.

In the subsequent computation I have taken it for granted that the clock correction is unknown and that the moment of the culmination must therefore be deduced from the observations themselves. This may be done graphically or by interpolation [1]), in that one forms from the three sets of observations, distributed on both sides of the meridian $a = \frac{z_2 \div z_1}{u_2 \div u_1}$, $b = \frac{z_3 \div z_2}{u_3 \div u_2}$, $c = \frac{b \div a}{u_3 \div u_1}$, where z and u are zenith distances and clock times expressed in seconds of arc and time respectively. Result: $u_0 = \frac{u_1 + u_2}{2} \div \frac{a}{2c} = \frac{u_2 + u_3}{2} \div \frac{b}{2c}$

The graphic method as well as the interpolation presupposes that the diurnal arc is divided symetrically by the meridian ɔ: constant declination. In latitudes as high as those which we are here dealing with, it will therefore be most correct to check the zenith distances for the variation of the declination, in other words, to refer the declination to the same moment for the whole of the series of observations. It is quite immaterial which moment one chooses; only the declination itself must be computed for the same moment.

From the table below the geocentric zenith distances with the adjunct $\Delta\delta$, designated I, III and VI, have been chosen for the computation of the clock time of the culmination. One might have chosen others, for instance instead of III one might have used IV, only II should be absolutely avoided, because there is every reason to suppose that this observation is encumbered with a very gross error.

Of the values in the table below one gets:

$$a = \frac{\div 32}{633} = \div 0.0505; \quad b = \frac{+21}{735} = + 0.0286;$$

$$c = \frac{+ 0.0791}{1368} = + 0.0000579.$$

$U_0 = 11^h38^m28^s + 7^m16^s = 11^h45^m44^s$ controlled by

$U_0 = 11^h49^m52^s \div 4^m07^s = 11^h45^m45^s$.

[1]) Marcuse: Handbuch d. geogr. Ortbestimmung, p. 232.

After this the reduction to the meridian is computed by the well-known formula $\frac{\cos\varphi\cos\delta}{\sin z} 2\omega\sin^2\frac{t}{2}$ where for φ, δ and z one uses approximate values f. inst. $\varphi = 82°26'.2$, $\delta = +16°18'$, $z = 66°08'.1$ whereas the factor $2\omega\sin^2\frac{t}{2}$ is taken from a table for the argument t (the hour angle) expressed in differences of the clock time.

	I	II	III	IV	V	VI
Watch	11h33m12s	11h39m55s	11h43m45s	11h47m45s	11h51m57s	11h56m00s
Read z	66°21'35"	66°21'12"	66°21'06"	66°21'03"	66°21'08"	66°21'14"
Level	+ 37	+ 4	+ 26	+ 33	+ 37	+ 33
Refr.	+ 2 27	+ 2 27	+ 2 27	+ 2 27	+ 2 27	+ 2 27
$\rho + \pi$	÷ 16 01	÷ 16 01	÷ 16 01	÷ 16 01	÷ 16 01	÷ 16 01
Geocentric z	66 08 38	66 07 42	66 07 58	66 08 02	66 08 11	66 08 13
$\Delta\delta$	0	+ 4	+ 8	+ 11	+ 13	+ 16
Reduction to the meridian	÷ 43	÷ 9	÷ 1	÷ 1	÷ 10	÷ 28
δ (11h33m12s)	+ 16 18 00	+ 16 18 00	+ 16 18 00	+ 16 18 00	+ 16 18 00	+ 16 18 00
φ	82 25 55	82 25 37	82 26 05	82 26 12	82 26 14	82 26 01

The computation shows what might a priori be expected, that the observation II fits very badly into the whole group. If it is excluded from the mean, we get $\varphi = 82°26'05" \pm 8"$.

The mean error indicated must be supposed to be too small, among other things because the time of the culmination is deduced from the observation series itself.

Latitude, midnight 15—16/V 1907 (observed by Koch without an assistant). ☋; $b = 769$ mm; $t = \div 15°$ C.; 1 division of the level = 20"; calm. Instrument placed on glare ice in the immediate vicinity of the coast off Kap Bridgman. l = about 1h46m west of Grw.; clock correction $s = \div 16^m30^s$.

Telescope left					Telescope right				
Clock time	Vernier		Level		Clock time	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
12h07m05s	282°38'.6	39'.3	12.7	6.0	12h09m05s	77°22'.3	23'.0	2.0	8.5
13 10	38.6	39.2	13.5	6.8	16 25	22.5	23.2	2.5	9.0
19 30	38.6	39.2	13.0	6.2	21 35	22.3	22.9	2.0	8.6

Estimate by second pair of observations

Telesc. left....	$360° \div 282°38'.9$	$= 77°21'.1$
Telesc. right.....		$77\ 22.9$
	Mean	$77°22'.0$
	Level $+$	0.7
	Refr. $+$	4.5
	$\rho + \pi$ $+$	15.7
	δ $+$	$18\ 47.6$
	$z + \delta$	$96°30'.5$
$\varphi = 180° \div (z + \delta)$		$= 83°29'.5$

As the clock correction is known, the proceeding at the computation of the time of culmination becomes the ordinary one:

Apparent time.....	$12^h00^m00^s$
Equation of time.....	$\div 3\ 49$
Clock correction	$\div (\div 16\ 30)$
Clock time of the culmination..	$13^h12^m41^s$

Clock time	$12^h08^m05^s$	$12^h14^m48^s$	$12^h20^m12^s$
Read z	$77°21'51''$	$77°21'59''$	$77°21'51''$
Level.....	$+ 41$	$+ 44$	$+ 43$
Refr.....	$+ 4\,45$	$+ 4\,45$	$+ 4\,45$
$\rho + \pi$	$+ 15\,42$	$+ 15\,42$	$+ 15\,42$
Geocentric z	$77\ 42\ 59$	$77\ 43\ 10$	$77\ 43\ 01$
Reduction to the meridian	$+ 5$	$+ 1$	$+ 12$
δ	$+ 18\ 47\ 30$	$+ 18\ 47\ 34$	$+ 18\ 47\ 37$
$z + \delta$.....	$96\ 30\ 34$	$96\ 30\ 45$	$95\ 30\ 50$
φ	$83\ 29\ 26$	$83\ 29\ 15$	$83\ 29\ 10$

$$\varphi = 83°29'17''.$$

The mean error may be estimated at about ten seconds.

If the local correction of the watch had not been known, one would from the series of observations have got the clock time of culmination $12^h15^m29^s$, from which one would in return have got three closely agreeing values of φ, i. e. $83°29'17''$.

Further I am going to give an example of a determination of latitude by the sun, performed with special care and under favourable conditions, and which consequently may be considered an expression of the greatest accuracy, which in observations of the sun may be obtained by means of the small universal instrument.

Latitude, noon 16/VIII 1908 (Observer Koch, Assistant Gundahl-Knudsen). $b = 702$ mm; $t = \div 11°$ C.; one division of the level $= 20''$; calm. Instrument placed on smooth inland ice about 8 kilometres east of Jættebrinken (giant's bluff). $l = 1^h34^m$ w. of Grw.; clock correction $s = +43^m10^s$.

Telescope left					Telescope right				
Clock time	Vernier A	Vernier B	Level Obs.	Level Obj.	Clock time	Vernier A	Vernier B	Level Obs.	Level Obj.
$11^h07^m32^s$	301°30′.1	30′.8	13.0	5.0	$11^h10^m34^s$	58°39′.7	40′.2	5.0	13.0
☌ 12 06	31.2	31.3	13.0	5.0	☌ 13 54	39.5	40·1	5 0	13.0
15 32	31.1	31.2	13.5	5.5	17 15	39.6	40.2	5.0	13.0
$11^h09^m06^s$	302°01′.8	02′.4	12.0	4.0	$11^h11^m13^s$	58°07′.7	08.6	4.0	12.0
☋ 12 56	02.5	02.9	13.0	5.0	☋ 14 33	07.5	08.4	5.0	13.0
16 24	02.4	02.7	13.5	5.5	18 05	07.7	08.6	6.0	14.0

Estimate by the two middle pairs.

Telesc. left ... $\begin{cases} 360° \div 301°31'.2 = 58°28'.8 \\ 360° \div 302°02'.7 = 57\ 57.3 \end{cases}$

Telesc. right ..... $\begin{cases} 58\ 39.8 \\ 58\ 07.9 \end{cases}$

Mean 58°18′.5
Level 0.0
Refr. $+\pi+$ 1.6
$\delta + 19\ 05.2$
$\varphi = 77°25'.3$

In the foregoing examples the reduction to the meridian has been computed corresponding to the mean of the clock times of every individual pair. Here where the utmost accuracy is aimed at, a facilitation of this kind will hardly be permissible, and the reduction must therefore be computed for each single pointing.

By using the values of φ, δ and z employed in the estimate we get the reduction to the meridian:

$$\frac{\cos\varphi\cos\delta}{\sin z} \times 2\omega \sin^2\frac{t}{2} = 0.579 \times 2\omega \sin^2\frac{t}{2}$$

Apparent noon..... $12^h00^m00^s$
Equation of time..... $\div$ 3 49
Mean time at apparent noon... $11^h56^m11^s$
Clock correction ..... $+$ 43 10
Clock time at apparent noon .. $11^h13^m01^s$

The hour angles corresponding to the single pointings are computed, and the value of $2\omega \sin^2 \frac{t}{2}$ is taken from a table. The multiplication $0.579 \times 2\omega \sin^2 \frac{t}{2}$ is performed by means of an engineer's scale.

	Clock	t	$2\omega \sin^2 \frac{t}{2}$	Reduction to the meridian
☌	11h07m32s	÷ 5m29s	59 } 36	21″
	10 34	÷ 2 27	12 }	
	12 06	÷ 0 55	2 } 2	1
	13 54	+ 0 53	2 }	
	15 32	+ 2 31	12 } 24	14
	17 15	+ 4 14	35 }	
☋	11 09 06	÷ 3 55	30 } 18	10
	11 13	÷ 1 48	6 }	
	12 56	÷ 0 05	0 } 2	1
	14 33	+ 1 32	4 }	
	16 24	+ 3 23	22 } 36	21
	18 05	+ 5 04	50 }	

		I	II	III
☌	Read z	58°34′37″	58°34′17″	58°34′23″
	Level.....	0	0	+ 5
	Refraction ..	+ 1 34	+ 1 34	+ 1 34
	$\rho + \pi$	÷ 15 58	÷ 15 58	÷ 15 58
	Geocentric z.	58 20 13	58 19 53	58 20 04
	Reduct. to m.	÷ 21	÷ 1	÷ 14
	δ	+ 19 05 10	+ 19 05 12	+ 19 05 14
	φ	77°25′02″	77°25′04″	77°25′04″

		IV	V	VI
☋	Read z	58°03′01″	58°02′37″	58°02′48″
	Level.....	0	0	÷ 5
	Refraction .	+ 1 32	+ 1 32	+ 1 32
	$\rho + \pi$	+ 15 42	+ 15 42	+ 15 42
	Geocentric z.	58 20 14	58 19 51	58 19 57
	Reduct. to m.	÷ 10	÷ 1	÷ 21
	δ	+ 19 05 10	+ 19 05 12	+ 19 05 14
	φ	77°25′14″	77°25′02″	77°24′50″

Mean: $\varphi = 77°25'03'' \pm 8''$.

If one takes it for granted that there is a systematic error of pointing at the limb of the sun, which, however, does not appear

from the series of observations — one ought, before forming an estimate of the mean error, first to have formed the means $\frac{I + IV}{2}$, $\frac{II + V}{2}$ and $\frac{III + VI}{2}$.

From the preceding it appears that on sledge trips one may count on being able to determine ones latitude by the sun — by means of the small Hildebrand universal instrument — with a mean error of about ten seconds, which accuracy is quite satisfactory for ordinary geographical purposes, and which in conditions, so difficult as those we are here dealing with, can hardly be attained by any other instrument.

The greatest source of error, as far as the universal instrument is concerned, is to be found in the level, which when travelling cannot be protected from the effect of radiation, and which consequently becomes sluggish. At star observations one may, when the temperature is not too low, carry the accuracy further, which the expedition has done in many cases. To conclude, I shall here give an observation of this kind, performed under particularly favourable conditions.

Pustervig, 6/XI 1907. Determination of latitude by Polaris (Observer: Koch; Assistant: Wegener). $b = 749$ mm; $t = \div 9°.6$; 1 division of the level = 20″; correction of sidereal chronometer 57203: $s = 1^h13^m41^s$; $l = 1^h24^m19^s$ w. of Grw.; declination of Polaris $\delta = 88°48'54''$.

Telescope right					Telescope left				
57203	Vernier		Level		57203	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$0^h10^m12^s$	11°59′.0	59′.7	4.3	14.0	$0^h14^m12^s$	348°11′.1	11′.8	11.0	1.8
17 28	59.0	59.8	4.2	13.9	20 35	11.0	11.9	11.1	1.7
23 23	59.2	59.7	4.0	13.8	26 29	10.8	11.7	11.0	1.6

For the computation of the latitude by Polaris there are special tables in the Nautical Almanac. Here we are going to use the formula:

$$\varphi = h \div p \cos t + \frac{1}{2\,\omega} p^2 \sin^2 t \tan h$$

where h is the altitude and p the polar distance. The observations are grouped in pairs, as in the earlier examples:

$p = 1°11'06'' = 4266''$.

57203	$0^h12^m12^s$	$0^h19^m02^s$	$0^h24^m56^s$
Correction	$+1\ 13\ 41$	$1\ 13\ 41$	$1\ 13\ 41$
Sidereal time	$1\ 25\ 53$	$1\ 32\ 43$	$1\ 38\ 37$
a	$1\ 26\ 53$	$1\ 26\ 53$	$1\ 26\ 53$
t	$\div\ 1^m00^s$	$+\ 5^m50^s$	$+\ 11^m44^s$
	$\div 0°15'00''$	$+1°27'30''$	$+2°56'00''$
$\log p$	3.6300	3.6300	3.6300
$-\cos t$	0.0000	9.9999	9.9994
$\log p \cos t$	3.6300	3.6299	3.6294
Read z	$11°53'57''$	$11°53'59''$	$11°54'06''$
Level	$\div\ 28$	$\div\ 27$	$\div\ 27$
Refraction	$+\ 13$	$+\ 13$	$+\ 13$
h	$78°06'18''$	$78°06'15''$	$78°06'08''$
$\div p \cos t$	$\div\ 1\ 11\ 06$	$\div\ 1\ 11\ 05$	$\div\ 1\ 11\ 00$
$+\frac{1}{2\omega} p^2 \sin^2 t \tan h$	0	0	$+\ 1$
φ	$76°55'12''$	$76°55'10''$	$76°55'09''$

As a mean we get $\varphi = 76°55'10''$ with a mean error of a couple of seconds.

Determinations of time.

Determinations of time are the most difficult astronomical observations in high latitudes, particularly under conditions where the latitude is not accurately known. The influence of an error of the latitude appears from a differentiation of

$$\cos t = \frac{\sin z \div \sin\varphi \sin\delta}{\cos\varphi \cos\delta}, \text{ which gives:}$$

$$\div \sin t\, dt = \frac{\div \cos^2\varphi \cos\delta \sin\delta + (\cos z \div \sin\varphi \sin\delta) \sin\varphi \cos\delta}{\cos^2\varphi \cos^2\delta} d\varphi;$$

$$\text{or } dt = \frac{\sin\delta \div \cos z \sin\varphi}{\cos\delta \sin t} \times \sec^2\varphi\, d\varphi$$

In $80° \sec^2\varphi =$ about 33 which very clearly indicates that even a slight uncertainty in the latitude, under certain circumstances, may produce a rather considerable uncertainty in the clock time.

From

$$dt = \frac{\sin\delta \div \cos z \sin\varphi}{\cos\varphi} \times \frac{1}{\sin t \cos\varphi \cos\delta} d\varphi = \div \frac{\sin z \cos A}{\sin t \cos\varphi \cos\delta} d\varphi$$

we see the well-known fact that the nearer to the prime vertical the determination of time is performed, the more independent it becomes of the latitude.

It thus follows that determinations of time ought to be performed as near to the prime vertical as possible, which demand, however, is not an easy one to meet in practice, where travelling and weather conditions often place obstacles in our way. Where the determination of time is only intended as a support for the determinations of latitude or azimuth, or to check the longitude, one may generally put up with a comparatively big uncertainty in the clock time; but if, on the other hand, the longitude is to be determined by the chronometer, one must take care to create the best possible conditions for the determinations of time.

As the watches used as chronometers ought not to be taken out more often or for longer periods than strictly necessary, a clock comparison between the chronometer and the observation watch will, as a rule, be necessary immediately before or after the observation.

At determinations of time it is very desirable to have an assistant to observe the watch and for recording purposes, but one may on an emergency do without him, in a similar manner as in the case of the latitude.

At observations of the sun one ought as a rule to observe the limb which eludes the thread, in other words, in the morning the lower limb, in the evening the upper. One then points slightly within the orbit of the sun (see Fig. 38; the arrow indicates the direction of the apparent movement of the sun) and waits for the moment, when the sun eludes the horizontal thread. As in this manner one can follow the movement of the sun across the threads, one gets the moment of taction with great sharpness, even in high arctic regions, where the day circle only inclines a few degrees towards the horizon.

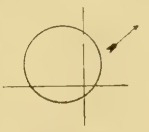


Fig. 38.

Kap Bridgman, 15/V 1907. Afternoon. Determination of time. Observer: Koch; Assistant: Bertelsen. ☋; b = 769 mm; $l = \div 10°.5$; $\varphi = 83°29'17''$; 1 division of the level = 20″; approximate clock correction to Grw. s = about $+ 1^h30^m$. Instrument placed on glare ice, in the immediate vicinity of the coast.

Telescope left					Telescope right				
Clock time	Vernier		Level		Clock time	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$6^h22^m14^s$	288°39′.7	40′.4	11.6	5.9	$6^h23^m28^s$	71°23′.1	23′.5	5.0	11.0
24 49	35.2	35.9	11.6	5.9	25 49	27.2	27.7	5.0	11.0
27 16	31.2	31.7	12.0	6.2	28 20	31.2	31.7	5.0	11 0

The observations are grouped in the usual way in three pairs, and every single pair is computed by the formula

$$\tan {}^1/_2\, t = \pm \sqrt{\sec\sigma \sec(\sigma \div z) \sin(\sigma \div \delta) \sin(\sigma \div \varphi)},$$

where $$\sigma = {}^1/_2 (z + \delta + \varphi).$$

Clock time	$6^h22^m51^s$	$6^h25^m19^s$	$6^h27^m48^s$
Correction to Grw.	c. + 1 30	+ 1 30	+ 1 30
Mean time at Grw.	$7^h.88$	$7^h.92$	$7^h.96$
Read z	71°21′37″	71°25′57″	71°30′00″
Level	+ 8	+ 8	+ 11
Refraction	+ 3 06	+ 3 07	+ 3 08
$\rho + \pi$	+ 15 43	+ 15 43	+ 15 43
Geocentric z	71 40 34	71 44 55	71 49 02
δ	18 44 07	18 44 08	18 44 09
φ	83 29 17	83 29 17	83 29 17
$2\,\sigma$	172 113 58	172 118 20	172 122 08
σ	86 56 59	86 59 10	87 01 14
$\sigma \div z$	15 16 25	15 14 15	15 12 12
$\sigma \div \delta$	68 12 52	68 15 02	68 17 05
$\sigma \div \varphi$	3 27 42	3 29 53	3 31 57
log sec σ	1.27399	1.27920	1.28421
— — $(\sigma \div z)$	0.01562	0.01554	0.01548
— sin $(\sigma \div \delta)$	9.96782	9.96793	9.96803
— — $(\sigma \div \varphi)$	8.78090	8.78543	8.78968
	0.03833	0.04810	0.05740
log tan $^1/_2\, t$	0.01917	0.02405	0.02870
t	92°31′.6	93°10′.2	93°47′.0
=	$6^h10^m06^s$	$6^h12^m41^s$	$6^h15^m08^s$
Equation of time	÷ 3 49	÷ 3 49	÷ 3 49
Mean time	6 06 17	6 08 52	6 11 19
Clock time	6 22 51	6 25 19	6 27 48
Correction	÷ 16 34	÷ 16 27	÷ 16 29

As a mean we get the clock correction $\div 16^m30^s$ with a mean error of three to four seconds of time (about 200 metres).

As was the case at the determination of latitude one may at the determination of time point both of the limbs of the sun, in order to escape systematic errors of pointing; in that case one ought not to let the sun elude the horizontal thread as indicated above, but one ought to point both limbs by means of the slow-moving screw.

The edge of the inland ice, 23/V 1908. Afternoon. Determination of time. Observer: Koch; Assistant: Gundahl-Knudsen. $b = 756$ mm; $t = \div 4.0$; one division of the level = 20″; φ

$= 77°28'45''$; approximate correction to Grw. $s = +2^h18^m$. Instrument placed on a moraine, in the immediate vicinity of the depot.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
$5^h12^m11^s$	289°39'.0	39'.1	11.9	6.9	$5^h13^m10^s$	70°41'.2	41'.8	6.3	11.3
☊ 14 16	32.0	32.3	11.7	6.7	☊ 15 19	48.2	48.9	6.0	11.0
☋ 16 12	289°57'.8	57'.8	11.3	6.5	☋ 17 12	70°22'.2	22'.9	6.0	11.0
18 00	52.0	52.1	11.0	6.0	18 59	28.2	29.0	5.0	10.0

After grouping the observations in pairs the below table is made.

	☊ I	☊ II	☋ III	☋ IV
Clock time K	$5^h12^m35^s.5$	$5^h14^m47^s.5$	$5^h16^m42^s$	$5^h18^m29^s.5$
Correction to Grw.	+2 18	+2 18	+2 18	+2 18
Mean time at Grw.	$7^h.51$	$7^h.55$	$7^h.58$	$7^h.61$
Read z	70°31'14''	70°38'12''	70°12'23''	70°18'17''
Level	+ 6	+ 7	+ 5	+ 12
Refraction	+ 2 50	+ 2 51	+ 2 47	+ 2 48
$\rho + \pi$	÷ 15 57	÷ 15 57	+ 15 41	+ 15 41
Geocentric z	70°18'13''	70°25'13''	70°30'56''	70°36'58''
δ	20 36 57	20 36 59	20 37 00	20 37 01
φ	77 28 45	77 28 45	77 28 45	77 28 45
2σ	168 23 55	168 30 57	168 36 41	168 42 44
σ	84°11'58''	84°15'29''	84°18'20''	84°21'22''
$\sigma \div z$	13 53 45	13 50 15	13 47 24	13 44 24
$\sigma \div \delta$	63 35 01	63 38 30	63 41 20	63 44 21
$\sigma \div \varphi$	6 43 13	6 46 44	6 49 35	6 52 37
log sec σ	0.99540	0.99977	1.00338	1.00725
$-\,-(\sigma \div z)$	0.01290	0.01279	0.01270	0.01261
$-\sin(\sigma \div \delta)$	9.95211	9.95232	9.95250	9.95269
$-\,-(\sigma \div \varphi)$	9.06825	9.07202	9.07504	9.07823
	0.02866	0.03690	0.04362	0.05078
log tan ½ t	0.01433	0.01845	0.02181	0.02539
t	91°53'.4	92°26'.0	92°52'.6	93°21'.0
$=$	$6^h07^m34^s$	$6^h09^m44^s$	$6^h11^m30^s$	$6^h13^m24^s$
Equation of time	÷ 3 28	÷ 3 28	÷ 3 28	÷ 3 28
Mean time	6 04 06	6 06 16	6 08 02	6 09 56
Clock time	5 12 36	5 14 48	5 16 42	5 18 30
Correction	+ 51 30	+ 51 28	+ 51 20	+ 51 26

As a mean we get the correction $= +51^m26^s$ with a mean error which may be estimated at above four seconds (about 400 metres).

When the declination of the sun becomes negative, the sun is practically inapplicable in determinations of time on sledge trips, because one must make the observation at too great a distance from the prime vertical. In order to attain the greatest possible accuracy one must thus use fixed stars or planets. The lighting of reticule, circles and level, by means of artificial light is, however, a most disagreeable thing on sledge trips in a low temperature. The small electric lamps are apt to fail, so that one has to have recourse to lanterns, and it has frequently occurred that I have been reduced to using an unprotected candle in the open air.

In order to avoid the inconvenience of the artificial light one ought to make use of the twilight. The reticule will then be visible without artificial light, nor will it during the lightest part of the twilight be necessary to light up the circles.

We have often to great advantage been able to observe Venus in the twilight. The following is an example of an observation of this kind:

Pustervig, 26/III 1908. Afternoon. Determination of time by Venus. Observer: Wegener; Assistant: Lindhard. b = 743 mm; $t = \div 17.6$; $\varphi = 76°55'10''$; 1 division of the level = 22″; sidereal chronometer No. 57203, correction towards Grw. $+ 2^h51^m41^s$.

Telescope left					Telescope right				
57203	Vernier		Level		57203	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$7^h16^m00^s$	289°55′.3	55′.4	11.8	5.0	$7^h18^m05^s$	70°12′.2	12′.0	5.0	11.8
20 03	42.2	42.3	12.3	5.6	21 56	25.3	24.8	4.8	11.3
23 59	29.0	28.8	12.2	5.5	25 56	39.0	38.9	4.2	11.0

The observations are grouped in three pairs.

Mean $s = + 1^h27^m23^s$ with a mean error of a couple of seconds (about 200 metres).

When in the autumn of 1907 the meteorological station was established in the inner part of Dove Bugt at Pustervig, it became necessary to determine the position of the station with the greatest possible accuracy. The requisite determination of latitude by Polaris is mentioned on pp. 271—272. The longitude had to be determined by means of a chronometric voyage — sledge trip — between Danmarks Havn and Pustervig. At Pustervig the clock correction was determined by zenith distance observations at two fixed stars. The observations at Pustervig were performed under circumstances which were the most

57203	$7^h17^m02^s$	$7^h20^m59^s$	$7^h24^m58^s$
Correction to Grw.	+ 2 51 41	+ 2 51 41	+ 2 51 41
Grw. sidereal time	$10^h.15$	$10^h.21$	$10^h.26$
Right ascension at transit at Grw..	3. 05	3. 05	3. 05
Hour angle at Grw.	$7^h.10$	$7^h.16$	$7^h.26$
Read z	70°08′23″	70°21′24″	70°35′01″
Level	0	+ 10	+ 14
Refraction	+ 2 55	+ 2 57	+ 2 59
Parallax	÷ 8	÷ 8	÷ 8
Geocentric z	70°11′10″	70°24′23″	70°38′06″
δ	+ 19 13 23	+ 19 13 25	+ 19 13 29
φ	76 55 10	76 55 10	76 55 10
2σ	166 19 43	166 32 58	166 46 45
σ	83 09 51	83 16 29	83 23 22
$\sigma \div z$	12 58 41	12 52 06	12 45 16
$\sigma \div \delta$	63 55 28	64 03 04	64 09 53
$\sigma \div \varphi$	6 14 41	6 21 19	6 28 12
log sec σ	0.92436	0.93141	0.93885
— — $(\sigma \div z)$	0.01124	0.01104	0.01085
— sin $(\sigma \div \delta)$	9.95344	9.95384	9.95426
— — $(\sigma \div \varphi)$	9.03653	9.04412	9.05186
	9.92557	9.94041	9.95582
log tan $^1/_2\, t$	9.96279	9.97021	9.97791
t	85°05′50″	86°04′24″	87°05′12″
=	$5^h40^m23^s$	$5^h44^m18^s$	$5^h48^m21^s$
α	3 04 01	3 04 02	3 04 02
Sidereal time	$8^h44^m24^s$	$8^h48^m20^s$	$8^h52^m23^s$
57203	7 17 02	7 20 59	7 24 58
Correction	+ $1^h27^m22^s$	+ $1^h27^m21^s$	+ $1^h27^m25^s$

favourable possible for sledge trip observations, but the result was, as it will appear, in no wise particularly good, possibly because the artificial light failed during the observation of γ Andromedæ.

The distrust of the existing tables of refraction met with, time after time, in arctic literature, caused us to select the one star in the eastern and the other in the western sky. This precaution was however, as shown by our subsequent investigations, quite superfluous in this case, where the zenith distances were comparatively small and the temperature not particularly low.

Pustervig, 6/XI 1907. Determinations of time by γ Andromedæ and ζ Herculis. Observer: Wegener; Assistant: Koch. b = 743 mm; t_1 = ÷ 10.6 (γ Andromedæ); t_2 = ÷ 11.2 (ζ Herculis);

1 division of the level = 20.″5; sidereal chronometer No. 57203, correction towards Grw. + $2^h38^m0^s$.

Telescope left					Telescope right				
57203	Vernier		Level		57203	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
					γ Andromedæ				
$20^h09^m43^s$	315°31′.0	30′.5	11.0	1.4	$20^h14^m01^s$	44°29′.5	29′.0	3.0	12.5
18 01	56.0	55.0	11.4	1.9	20 45	06.5	06.5	3.1	12.6
23 10	316 13.0	12.5	12.2	2.7	25 52	43 50.5	50.0	2.8	12.2
					ζ Herculis				
$20^h47^m38^s$	303°02′.5	02′.0	12.3	2.9	$20^h51^m38^s$	57°22′.0	21′.5	1.0	10.6
56 13	302 33.5	33.0	13.5	3.9	21 01 39	56.5	56.0	1.2	10.8
21 05 42	01.5	01.0	12.9	3.4	11 22	58 29.0	28.5	1.0	10.6

The computation given below is quite analogous with the examples given above.

	γ Andromedæ			ζ Herculis		
Read z	44°29′15″	44°05′30″	43°48′45″	57°09′45″	57°41′30″	58°13′45″
Level	÷ 16	÷ 12	÷ 1	+ 18	+ 28	+ 24
Refraction	+ 1 01	+ 1 00	+ 1 00	+ 1 36	+ 1 37	+ 1 39
Geocentric z	44°30′00″	44°06′18″	43°49′44′	57°11′39″	57°43′35″	58°15′48″
δ	41 53 17	41 53 17	41 53 17	31 46 24	31 46 24	31 46 24
φ	76 55 10	76 55 10	76 55 10	76 55 10	76 55 10	76 55 10
2σ	162 78 27	162 54 45	162 38 11	165 53 13	166 25 09	166 57 22
σ	81°39′44″	81°27′23″	81°19′06″	82°56′37″	83°12′35″	83°28′41″
$\sigma \div z$	37 09 44	37 21 05	37 29 22	25 44 58	25 29 00	25 12 53
$\sigma \div \delta$	39 46 27	39 34 06	39 25 49	51 10 13	51 26 11	51 42 17
$\sigma \div \varphi$	4 44 34	4 32 13	4 23 56	6 01 27	6 17 25	6 33 31
log sec σ	0.83861	0.82809	0.82118	0.91096	0.92725	0.94468
— — $(\sigma \div z)$	0.09858	0.09967	0.10047	0.04548	0.04445	0.04354
— sin $(\sigma \div \delta)$	9.80602	9.80414	9.80287	9.89154	9.89316	9.89478
— — $(\sigma \div \varphi)$	8.91741	8.89819	8.88479	9.02097	9.03968	9.05774
	9.66062	9.63009	9.60931	9.86895	9.90454	9.94074
log tan $^1/_2 t$	9.83031	9.81505	9.80466	9.93448	9.95227	9.97037
t	÷ 68°09′.7	÷ 66°18′.4	÷ 65°03′.4	+ 81°23′.4	+ 83°43′.0	+ 86°05′.6
=	÷ $4^h32^m39^s$	÷ $4^h25^m14^s$	÷ $4^h20^m14^s$	+ $5^h25^m34^s$	+ $5^h34^m52^s$	+ $5^h44^m22^s$
α	1 58 15	1 58 15	1 58 15	16 37 47	16 37 47	16 37 47
Sidereal time	$21^h25^m36^s$	$21^h33^m01^s$	$21^h38^m01^s$	$22^h03^m21^s$	$22^h12^m39^s$	$22^h22^m09^s$
57203	20 11 52	20 19 23	20 24 31	20 49 38	20 58 56	21 08 32
Correction	+ $1^h13^m44^s$	+ $1^h13^m38^s$	+ $1^h13^m30^s$	+ $1^h13^m43^s$	+ $1^h13^m43^s$	+ $1^h13^m37^s$
Mean		$1^h13^m37^s$			$1^h13^m41^s$	

From the result it will appear at once that the observation of γ Andromedæ is not good, and there is every justification for thinking that a considerable error must have crept into the 3^{d} pair of observations.

However, the observation journal contains no remark to this effect, so that from a purely theoretical point of view this pair of observations should scarcely be condemned. At observations of this kind, theoretical considerations are, however, of no great importance. In practice it will undoubtedty be most correct to condemn the whole observation of γ Andromedæ and stick to ζ Herculis.

In all the hitherto given examples, from determinations of latitude as well as from those of time, we have exclusively had to do with observations of zenith distances, the most primitive of all methods, and consequently the most suitable on sledge trips, where the conditions are also very primitive. When gradually realizing the considerable accuracy which might be attained by means of zenith distance observations with the small Hildebrand universal instrument, the question presented itself, whether we might not, by other methods, carry the accuracy still further. As a rule, a greater accuracy than the one attained through our zenith distance observations was not essential from a practical point of view, but in exceptional cases tasks might occur, where a higher degree of accuracy would be desirable, for instance, at the above-mentioned determination of longitude between Danmarks Havn and Pustervig in the autumn of 1907.

With the large instrument permanently set up in the Observatory the determinations of time, in the course of the winter, were nearly always performed by transits on the vertical of α or λ Ursæ Minoris. It was therefore, quite natural that we should try whether this method might be suitable for the small travelling instrument. For this purpose we used the travelling universal instrument No. 3521, which had a particular reticule, with three vertical threads.

The method is explained on p. 116.

The observation was performed in the open air, in the shelter of the house at Danmarks Havn. As usual, the instrument was placed on the transportable tripod. During the observation the horizontal axis was covered with rime, which had to be wiped off, together with that on the feet of the level of the axis. For this purpose a stick covered with chamois leather would have been very convenient, but as we did not possess it, we had to use a piece of ordinary chamois leather. In the same manner the readings of the level became rather uncertain, which is particularly awkward in high latitudes. The computation also seems to show that the reading of the level is encumbered with grave errors; particularly in the case of γ Piscium,

Danmarks Havn 29/X 1907. Determination of time in the vertical of Polaris. Observer: Koch; Assistant: Wegener; $t = \div 16°$; 1 division of the level, $p = 30''$; $1\, p \sec\varphi = 8^s.7$.

Elements of pointing.

Star	Magnitude	Approximate clock time of the transit	Approximate zenith distance
α Urs. Min. ...	2.1	21^h20^m	12°20′
η Pegasi	3.1	21 28.2	47 03
μ Pegasi	3.7	21 34.7	52 40
α Pegasi	2.6	21 48.8	62 04
γ Piscium	3.8	22 00.7	74 00

The Observation.

Circle	57203	Level W	Level E	Computation	Circle	57203	Level W	Level E	Computat.
E	α Urs. Min.	3.1	7.2	$\div 0.45$	W	α Urs. Min.	6.9	2.9	$+ 0.25$
	$21^h25^m41^s.0$	6.3	2.2	$\div 0.56$		$21^h45^m59^s.5$	2.4	6.4	$+ 0.01$
	η Pegasi	6.1	2.0	$\div 0.70$		α Pegasi	2.6	6.8	$\div 0.22$
	21 27 44.9	3.3	7.6			21 48 58.9	6.3	2.2	
	28 15.1					49 25.8			
	45.3					53.2			
W	α Urs. Min.	6.3	2.2	$\div 0.18$	E	α Urs. Min.	3.4	7.6	$\div 1.00$
	21 31 32	2.5	6.7	$\div 0.09$		31 56 26	5.5	1.5	$\div 0.99$
	μ Pegasi	2.8	6.9	$\div 0.00$		γ Piscium	5.0	1.0	$\div 0.98$
	21 34 44.0	6.9	2.8			22 00 55.8	2.9	7.0	
	35 13.2					1 22.6			
	42.8					49.2			

Computation (For further particulars see p. 116).

$U'_0 = \alpha' \div du_0 = 1^h26^m55^s \div 1^h22^m30^s = + 4^m25^s$.

	Circle east η Pegasi	Circle west μ Pegasi	Circle west α Pegasi	Circle east γ Piscium
δ	29°44′.4	24°06′.9	14°42′.6	2°46′.7
$\frac{4 \sin(\varphi \div \delta)}{\cos\delta}$	3.371	3.484	3.654	3.849
U' (α Urs. Min.)	$21^h25^m.7$	$21^h31^m.5$	$21^h46^m.0$	$21^h56^m.4$
$t' = U' \div U'_0$	21 21.3	21 27.1	21 41.6	21 52.0
a'_n	+ 213′.3	+ 206′.9	+ 190′.6	+ 178′.4
$t = a_n \frac{4 \sin(\varphi \div \delta)}{\cos\delta}$.	$+ 11^m59^s.0$	$+ 12^m00^s.8$	$+ 11^m36^s.5$	$+ 11^m26^s.6$
α	22 38 40.6	22 45 33.0	23 00 09.9	23 12 22.9
Sidereal time	22 50 39.6	22 57 33.8	23 11 46.4	23 23 49.5
U	21 28 15.1	21 35 13.3	21 49 26.0	22 01 22.1
$i \sec\varphi$	÷ 4.9	÷ 0.8	+ 0.1	÷ 8.6
Correction, du	+ 1 22 29.4	+ 1 22 21.3	+ 1 22 20.3	+ 1 22 35.6
Mean	$+ 1^h22^m25^s.4$		$+ 1^h22^m28^s.0$	

where the correction of the level is greatest and very much deviating from the others, the result differs a good deal from the other three.

As the thread intervals were not known, we have simply used the mean of the transits above the three threads. Collimation correction is not applied, because the collimation had not been determined.

The result is not altogether bad, and the certainty of the readings of the level — the weak point of the method — might perhaps, as mentioned above, also be increased. Still the experiment clearly indicates — as might a priori also be expected — that with an instrument as primitive as the little travelling universal instrument one ought to restrict oneself to the primitive zenith distance observation.

Determinations of azimuth.

Whereas in the case of determinations of latitude and time one will nearly always be protected against the influence of gross errors, because already before the observation one obtains a rather good idea of the latitude and time, this is not the case as far as the azimuth is concerned. It is true that one may attain some control by means of the compass; but the slight horizontal intensity in high latitudes makes even a very sensitive compass so slow-working that one can hardly trust it within a few degrees. Consequently a deeply rooted distrust is quickly felt respecting this instrument, and its use is avoided as much as possible. Fortunately it is easy enough to attain control without having recourse to the compass, when the observation is arranged in such a manner that the azimuth may be computed both by zenith distance and time. This demands a simultaneous pointing of the sun (the star) both on the horizontal thread and on the vertical thread (Fig. 39), which dexterity one quickly acquires by a little practice. Where the greatest accuracy has to be achieved, a proceeding of this kind is perhaps objectionable, because a simultaneous pointing of the two limbs will, in reality, easily result in perceptible errors[1]); but, as a rule, the utmost accuracy is not demanded in the case of determinations of azimuth on sledge trips. An error of 10′ in the azimuth will in

Fig. 39.

[1]) If the utmost accuracy is to be attained, the azimuth must, I think, be determined at noon or midnight by pointing the easterly or westerly limb of the sun, but without measuring the zenith distance at the same time. The azimuth will then be determined by the hour angle only, and therefore requires good determinations of time on both sides of the observation of azimuth, besides, of course, a good determination of latitude. On the Danmark-Ekspedition this method was never used on the slege trips.

most cases be of no importance; but an error as great as that will only occur rarely, even in very unfavourable circumstances. The previously indicated manner of pointing by touching the two limbs of the sun is, therefore, not necessary; one may very well take the liberty to bisect the centre of the sun, as indicated in Fig. 40, which manner of pointing was almost exclusively used on the Danmark-Ekspedition.

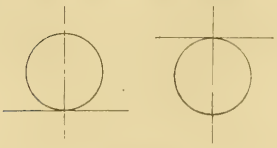


Fig. 40.

As the observation, as seen above, may be made in a very cursory way, it is not necessary to take more than two pointings one with "telescope left" and one with "telescope right". The error of the azimuth due to the inclination of the horizontal axis is trifling in this connection; hence the reading of the level of the axis is superfluous.

In case the azimuth is to be determined by the zenith distance, the greatest accuracy is attained by performing the observation in the prime vertical; on the other hand, in case the azimuth is to be computed by time, the best result is attained, when the hour angle is near 0° or 180°. In high latitudes where the inclination of the day circle towards the horizon — $90° \div \varphi$ — is inconsiderable, the hour angle may, however, be used through all the twenty-four hours for the determination of the azimuth; on the other hand a determination of the azimuth by the zenith distance becomes extremely uncertain, when the heavenly body is near the meridian. This fact plays a part in the valuation as to which of the two results one should ascribe the greater accuracy to. In case the observation is taken near the meridian, the determination by the zenith distance may be used as a sort of rough and ready control.

One might, from the above general remarks, perhaps be tempted to believe that it would be practicable to use the determination of azimuth promiscuously with the observation of time and latitude. The observation being a zenith distance observation, only presenting the particular feature that the vertical thread is to pass through the centre of the sun (to touch upon the limb of the sun) and that the horizontal circle is to be read, it would only be necessary, in the course of the determination of time and latitude, to observe these two things, in order to be able to compute both azimuth and time or latitude by the observation. In this manner one could also dispense with an observation, which in the difficult conditions, under which the work is often done, would mean a not inconsiderable alleviation. However, I warn people against permitting themselves an alleviation of this kind, because the observations of time and latitude thus become more complicated; the continuity of a series of observations

suffers thereby; the observation lasts longer; the taction of horizontal thread and limb becomes less reliable, because one has at the same time to look to the vertical thread; in short, observations of time and latitude would by such a proceeding become less accurate.

Below I shall give two examples of observations of azimuth, both from the most northerly station of the expedition at Kap Bridgman ($\varphi = 83°29'.3$). The first observation which was taken immediately after the afternoon time observation (see pp. 273—274) could not be used, because the fog set in, before the directions at the various terrestrial objects had been measured. A second azimuth observation was made immediately after the midnight latitude (see pp. 267—268). The peak of a single mountain had, however, been pointed after the first observation of azimuth, and as the same peak was also sigthted immediately after the midnight observation, a comparison between the results is possible.[1])

For the final computation at home the following formulæ are used:

$$\tan {}^1/_2\, a = \pm \sqrt{\sec \sigma \cos (\sigma \div z) \sin (\sigma \div \varphi) \operatorname{cosec} (\sigma \div \delta)},$$

where $$\sigma = {}^1/_2 (\varphi + \delta + z);$$

$$\cot a = \frac{\sin \varphi \cos t \div \cos \varphi \tan \delta}{\sin t}$$

At the introduction of the auxiliary angle M determined by $\tan M = \tan \delta$ sect the latter expression is converted into

$$\tan a = \tan t \cos M \operatorname{cosec} (\varphi \div M)$$

The rough computation during the sledge trip is made by the formula $\sin a = \frac{\sin t \sin (90° \div \delta)}{\sin z}$ by means of the table on p. 263.

Kap Bridgman 15/V 1907. Afternoon. Determination of azimuth. Observer: Koch; Assistant: Bertelsen; $\oplus$; $b = 769$ mm; $t = \div 10.5$; $\varphi = 83°29'.3$; approximate clock correction to Grw. $s_{Grw.}$ = about $+ 1^h30^m$; local clock correction: $s = \div 16^m30^s$. One division of the level = 20″. Instrument placed on glare ice in the immediate vicinity of the coast.

Telescope	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	
left	$6^h32^m22^s$	288°22′.4	23′.1	11.8	6.0	346°02′	153°.7	152°.7
right	34 32	71 41.8	42.4	5.0	11.0	346 36		
	Peak No. 42					311°41′		

[1]) As the azimuth during the first observation was conveyed to a peak it seems superpluous to undertake a new determination of azimuth, when the fog lifted. Why we did it I do not know.

As the determination of time for the day in question was only computed after our return, we did not know the exact clock correction while travelling. In order to get an approximate idea of the clock correction to be used in the course of the rough computation, use is made of the observation series in the subsequent midnight latitude (see pp. 267—268), which is performed in the same place. From the readings on the vertical circle in this series of observations it appears that the clock time of the culmination may be put at 12^h14^m. Hence it follows that clock correction ÷ equation of time = about 14^m. The result of the observation of azimuth may now, at an estimate, be computed in the following manner (see table on p. 263).

Clock time	6^h33^m
Correction ÷ equation of time ÷	14^m
Apparent time t	$= 6^h19^m = 12^h \div 5^h41^m$, log sin 5^h41^m 999
$90 \div \delta$	$= 71°.3$, log sin $71°.3$ 977
z	$= 72°.0$, log cosec $72°.0$ 22
	log sin a 998
	$a = \text{N } 84° \text{ W} = \text{S } 96° \text{ W}$

It will be seen below that the azimuth found in this manner deviates about 1°22′ from the true value. The result of the estimate is, however, sufficiently accurate for the making of a rough and ready map sketch on the sledge trip itself.

Computation

Watch K	$6^h33^m27^s + 1^h30^m = 8^h.05$	Grw. mean time of the observation
Correction	÷16 30	
Equation of time	(+)3 49	
t	$6^h20^m46^s = 95°11'.5$	

Read z	71°39′40″
Level	+ 9
Refraction	+ 3 10
$+ \rho \div \pi$	+ 15 43
Geocentric z	71°58′.7
φ	83 29 .3
δ	18 44 .2
2σ	174°12′.2

σ	87°06′.1	log cec	1.29616
$\sigma \div z$	15 07 .4	— cos	9.98469
$\sigma \div \varphi$	3 36 .8	— sin	8.79950
$\sigma \div \delta$	68 21 .9	— cosec.....	0.03173
			0.11207
		log tan $^1/_2\, a$	0.05604
		a = ...	97°22′
		Horizontal circle	346 19
		Meridian point..	248°57′
		Peak No. 42	311 41
		Azimuth of Peak No. 42	S 62°44′ W

The compass is read off in order to get an idea of the magnetic declination, which is here 153°.2 ÷ 97°.1 = 56°.1 west.

Control computation by the hour angle.

log tan δ..	9.54045	log tan t.....	1.04163_n
— sec t..	1.04341_n	— cos M.....	9.41120_n
log tan M.	0.57386_n	— cosec ($\varphi \div M$) .	0.43692_n
M	104°56′.2	log tan a	0.88975_n
$\varphi \div M$ ...	÷ 21 26 .9	Control: a	97°21′

In the subsequent example from the same station, where the observation of azimuth was taken immediately after the midnight latitude and thus near the meridian, the hour angle, as a matter of course, gives a much more reliable result than the zenith distance; the latter may only serve as a very rough and ready control.

Kap Bridgman, Midnight 15—16/V 1907. Determination of azimuth. Observer: Koch; Assistant: Bertelsen; ⊕; b = 769 mm; t = ÷ 15.3; φ = 83°29′.3; approximate clock correction to Grw.; $s_{Grw.}$ = about + 1^{h}30^m; local correction = ÷ 16^{m}27^s; one division of the level = 20″. Instrument placed on glare ice in the immediate vicinity of the coast.

Telescope	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Horizontal circle
left.....	12^{h}28^{m}20^s	282°08′.1	8′.8	13.0	7.0	165°39′
right	29 39	77 52.1	52.6	2.8	8.4	166 00
	Peak No. 42	274°59′.9	60′.3	13.5	6.5	44°33′
	— —	85 01.7	02.1	4.7	11.1	

Rough Computation. When the sun is near the meridian one may, in high latitudes, as the first approximation put the azimuth equal to the hour angle. Seeing that an examination of the midnight latitude (see p. 267) as in the preceding example gives clock correction ÷ equation of time equal to about ÷ 14^m we get

Watch K	12^h29^m
Clock correction ÷ equation of time	÷ 14^m
Apparent time $t = a =$	12^h15^m = N 4° E

Computation

Watch K	$12^h29^m00^s$ ÷ 1^h30^m = c $13^h.0$	(Grw. mean time of the observation.
Correction	÷ 16 27	
Equation of time	÷ (÷ 3 49)	
t	$12^h16^m22^s$ = 184°05′.5	

Read z	77°51′57″
Level	+ 44
Refraction	+ 4 56
÷ ρ ÷ π	÷ 15 59
Geocentric z	77°41′.6 δ = 18°47′.7

log tan δ	9.53190	log tan t	8.85452
— sec t	0.00110_n	— cos M	9.97609_n
log tan M	9.53300_n	cosec (φ ÷ M)	0.01013_n
M	161°09′.6	log tan a	8.84074
φ ÷ M	÷77°40′.3	a	183°57′.9
		Horizontal circle	165 49.5
		Meridian point	341°52′
		Peak No. 42	44 33
		Azimuth of Peak Nr. 42	S 62°41′ W

If one makes a comparison with the value of the azimuth of Peak No. 42 as determined in the course of the afternoon, one sees that the difference between the two values is only three minutes.

The value of the midnight azimuth computed on the basis of the hour angle, a = 183°57′.9, may thus only be encumbered with an error of a few minutes. Knowing this, it may be of interest to perform the controlling computation of the midnight azimuth on the basis of the zenith distance, in order to form an idea of the importance which can be ascribed to a control of this kind.

Controlling computation by the zenith distance.

z	77°41′.6		
φ	83 29′.3		
δ	18 47′.7		
2σ	179°58′.6		
σ	89°59′.3	log sec	3.69118
$\sigma \div z$	12 17 .7	— cos	9.98992
$\sigma \div \varphi$	6 30 .0	— sin	9.05386
$\sigma \div \delta$	71 11 .6	— cosec	0.02383
			2.75879
		log tan $^1/_2 a$	1.37940

Control: $a = \div 175°13' = + 184°47'$

A control of this kind showing a difference of 50′ from the value to be controlled is of course quite unsatisfactory, but it is a question whether one could expect a much better one, because the azimuth so near the meridian varies rapidly, whereas the zenith distance varies comparatively very slowly.

A test of the significance of the control is most easily undertaken by examining the value of Δz, when Δa is put equal to 50′, or which by approximation comes to the same thing, when Δt is put equal to 3^m. For this purpose one may use the formulæ of the reduction to the meridian in the term

$$\varphi = 180° \div \delta \div z \div Am + A^2 \cot(\varphi + \delta) n \text{ (lower culmination)},$$

where $A = \cos\varphi \cos\delta \operatorname{cosec}(\delta + \varphi)$, $m = \frac{2 \sin^2 {}^1/_2 t}{\sin 1''}$, $n = \frac{2 \sin^4 {}^1/_2 t}{\sin 1''}$.

The last term of the formula, $A^2 \cot(\varphi + \delta) n$, can here be left out as being of no importance.

As the hour angle corresponding to the mean of the clock times of the two pointings is $12^h16^m22^s$, the two values of t, for which the reduction Am is to be computed, may conveniently be put at

$t_1 = 12^h15^m$ and $t_2 = 12^h18^m$.

$\varphi = 83°29'.3$; $\delta = 18°47'.7$

log cos φ	9.0546	
— — δ	9.9762	
— cosec $(\delta + \varphi)$	0.0101	
— A	9.0409	9.0409
— m [1])	2.6451	2.8034
— Am	1.6860	1.8443
Am	48″.5	69″.9

$\Delta z = 69''.9 \div 48''.5 =$ c. 0′.4.

[1]) log m is taken from table 29 in: Th. Albrecht, Formeln und Hülfstafeln für geographische Ortsbestimmungen, 3. Auflage, Leipzig 1894.

The difference found above of 50′ in the azimuth would thus arise by an error of 0′.4 on the zenith distance. Such an error on the zenith distance, measured by a single pair of observations is, it is true, rather great, though not greater than that it must arise rather frequently (cf. for instance second pair of observations in noon latitude, 6/V 1907, pp. 265—267).

Determination of Longitude during the Sledge Trips to Kap Bridgman in 1907 and to Dronning Louise's Land in May 1908.

In the course of the preparation of the maps it appeared that nearly all of the observation stations in Skærfjorden and Dove Bugt might be connected with the triangulation stations proper, either through a complete trigonometric station pointing or through a favourable azimuth at a previously determined station, in connection with a determination of latitude. As far as these stations were concerned, there was thus no occasion to have recourse to the more uncertain determination of the longitude by means of the watch.

During the two above-mentioned sledge trips a connection with the triangulation stations was, however, not possible. The determination of the longitude by transport of the watch came to play a considerable part during these sledge trips, and there may consequently be every reason to look somewhat more closely at the results obtained in this manner.

The sledge trip to Kap Bridgman in 1907.

In March 1907 I had determined the correction and rate of the below-mentioned watches to be used on the sledge trip.

The 26/III 1907, forenoon.

Watch	Clock time	Correction to Danmarks Havn	Rate in twenty-four hours of the clock	Given to
K	8h00m00s	+ 10m32s.5	+ 10s.6	Koch
57203	7 10 40	+ 59 28.7	+ 3m51.3	Koch
57508	8 04 00	+ 6 00.2	+ 2.4	G. Tostrup
57332	8 04 00	+ 6 17.4	+ 4.4	Hagen

Watch *K* was an ordinary, good pocket watch, which was to be used as an observation watch. The three other watches were Carrusel pocket chronometers from Bonniksen, Coventry. Watch 57203 was regulated to sidereal time, which was of course impracticable on a spring journey; it had, however, to be taken along in order to replace a mean time chronometer, the glass of which was broken.

Besides the above mentioned four watches a fifth good pocket

watch, which was assigned to BISTRUP, was included in the daily clock comparisons.

In order to protect our watches against the cold, we carried them on our breasts in little bags hung round our necks.

On sledge trips the duration of the working day varies a good deal. The wish to exploit favourable weather conditions or to get as far as a certain point, unexpected hunting, damage to our sledges or other delays may cause the working day to be extended over a period of thirty to forty hours. Under conditions of this kind the watches are very liable to stop. In order to diminish this risk we wound them twice daily, which means proved very effective and prevented the stopping of our watches.

The watches were compared once a day and their relative rate promptly computed. From the watch rate journal it appears that they maintained a fairly regular rate; only watch *K*, used as an observation watch, has on a single occasion, from 13/IV—15/IV, shown marked irregularities amounting to about 10^s.

The ten sledges which took part in the great sledge trip of 1907 were divided into four parties, each with their particular cartographic task. According as each party separated from the rest, the clock comparison had to be abandoned in the case of the watch belonging to that party. The first party (BISTRUP and RING) turned back at the Mallemukfjældet 80°9′ on April 22nd; the second party (G. THOSTRUP and WEGENER) turned back from Amdrup's Land 80°43′ on April 26th; and finally the two remaining sledge parties parted company on May 1st, west of Nakkehoved, 81°43′.

The chronometer 57508 was lost with MYLIUS ERICHSEN'S sledge party which perished, and the determination of longitude by transport of the watch thus came to rest, practically speaking, exclusively on chronometer 57203 in connection with watch *K*, both of which were carried by me. The importance of the watch comparisons, therefore, in the main only consists in the fact, that each of the sledge parties, according as they parted from the rest, were provided with a watch, the rate of which in the course of a month's travelling might be supposed to have become settled under daily control according to the particular travelling conditions. It must, however, be supposed that the rate of the watches on the sledge trip differed from the one at home in the station at Danmarks Havn. The value of the rate was, therefore, unknown from the very start; it became the affair of the individual cartographers to determine it in the course of the sledge trip or at the latest on the return to Danmarks Havn.

During the journey in a northerly direction, when the sky was constantly clear, I had practically speaking taken determinations of

time at all our camping places, often both in the forenoon and in the afternoon. The object of this was, among other things, that the individual sledge parties, on the return journey, by renewed determinations of time at the same places, should become able to determine a mean value of the rate within the period, which had elapsed between two such determinations in the same place.

This measure did not come to play the part anticipated. The sledge parties of Bistrup and G. Thostrup were, for cartographical purposes, obliged to choose other routes for the return journey than those followed on the way out, and so only in a few cases did they come to pass the old camping sites; Mylius Erichsen's party never returned at all, and my party on its return journey met with such foggy weather that only in two places—at Lambert's Land, 78°09′, and at Peary's Cairn 82°58′ did we succeed in getting determinations of time in the old camping sites.

On the return journey G. Thostrup was obliged to use chronometer 57508 as an observation watch and ordinary timekeeper. It must, therefore, be supposed that the rate of this watch has been less reliable than that of chronometer 57203, which during the whole journey was only taken out in order to be wound and for clock comparisons; it is, however, not actually substantiated by Thostrup's observations that the rate of chronometer 57508 varied in any material degree. (Before we started the daily rate was $+2^s.4$; during the return journey it was on an average 0^s).

As to chronometer 57203 and watch *K* the rate is as given in the table below:

Place of observation	Date	Clock time	Local correction	Intervals in days at twenty-four hours of the clock	Mean rate in twenty-four hours of the clock	Rate before the start
Chronometer 57203						
Danmarks Havn	26/III	7h.18 a. m.	+ 59m29s	89d.17	÷ 3m54s.8	÷ 3m51s.3
— —	23/VI	11h.37 a. m.	÷ 4h49 30			
Lamberts Land	12/IV	8h.17 a. m.	÷ 09 07	62 .64	÷ 3 54.4	
— —	13/VI	11h.46 p. m.	÷ 4 13 46			
Peary's Cairn	21/V	8h.14 p. m.	÷ 2 27 37	7 .58	÷ 3 56.8	
—	13/V	10h.08 a. m.	÷ 2 57 31			
Watch *K*						
Danmarks Havn	26/III	8h.00 a. m.	+ 10 33	88d.92	+ 4.2	+ 10s.6
— —	23/VI	5h.96 a. m.	+ 17 28			
Lamberts Land	12/IV	7h.84 a. m.	+ 10 33	62 .46	+ 4.7	
— —	13/VI	6h.97 p. m.	+ 15 26			
Peary's Cairn	13/V	5h.72 p. m.	÷ 2 27	7 .58	+ 1.7	
—	21/V	7h.11 a. m.	÷ 2 16			

If we compare the clock rate before the beginning of the journey with the mean clock rate for its whole duration, it appears that the influence of travelling conditions on the rates of the two watches, Δu, is the same, in that $\Delta^2 u$ for both of them is negative. In the case of 57203 the change in the rate is $\div 3^s.5$, as regards watch K $\div 6^s.4$. It must, therefore, be supposed that the rate, particularly during the early part of the trip, has varied somewhat. After 12/IV one must take it for granted that the watches have adjusted themselves to the particular travelling conditions, and have become relatively balanced. Therefore, I have not hesitated exclusively to use the value $\Delta u = \div 3^m54^s.4$ at the computations of the longitudes. The value of Δu which is obtained by means of the two determinations of time at Peary's Cairn, deviates, it is true, considerably from this one; but I have not dared to ascribe any decisive importance to the value determined at Peary's Cairn, because the observation on 21/V was conducted under most unfavourable conditions. Not only was the sun rather far removed from the prime vertical — the hour angle was about $\div 4^h55^m$ — but the observation was performed in fog and without using coloured glass. In the observation journal the following entry is made: "During the first two pairs of determinations limb of the sun dim". As regards both of the determinations of time at Peary's Cairn it holds good that they were undertaken without the use of a tripod. Finally it is to be borne in mind that nearly all the series of observations performed in Peary Land after 7/V bear testimony to the fact that I was so worn out and ill that I was not able to strain my attention to the same degree as I was wont to do (see the section: Extract of Koch's Diary). Under conditions of this kind, an error of 10^s to 20^s in the determination of time may easily occur. As the interval between the two determinations of time is only seven days and a half, it appears that the uncertainty of the observation on 21/V is in itself sufficient to explain away the deviation from the value $\div 3^m54^s.4$, found through the computation. The circumstance that watch K for the same period shows quite a similar deviation with the same sign points further in the direction that the cause must be looked for in an unfavourable observation of the sun and not in the watch.

From what has been indicated above it appears that the longitudes would necessarily become more uncertain than was desirable, if they were to be determined solely by means of the chronometer 57203. This was, however, not the case.

The fact that the sledge journey in 1907 in the main took place in north-south we used to its full extent to determine the positions of the stations by latitude, in connection with a favourable azimuth in

a southerly or northerly direction. The direct connecting of station to station in this manner is only rarely possible during forced sledge trips; the station must, as a rule, be selected immediately at the camping site on the sea ice or on the low-lying foreland, and so it cannot be pointed from the subsequent station. On the other hand it was very often possible in Northeast Greenland to make use of rocky knolls on projecting points and headlands, easily discernible rocky holms and finally also high, clearly defined mountain peaks, which might be visible during several marches. While travelling north I paid particular attention to the choice of points thus suitable as points of support for the determination of position. By determining the direction at these points from the varions stations, I succeeded in reality in establishing the connection, by means of azimuth, all the way from Rekvedøen (drift wood island[1]) to Amdrups Land, 80°43′. Past the Nordost-Rundingen, where the ice free land only consists of a narrow strip of gravel, and where the nunataks do not penetrate the inland ice, the azimuth connection failed for the first time; so the longitude of Nordost-Rundingen and Nakkehoved are determined by the watch, with a rather safe control through courses and distances from Amdrups Land. On the voyage across Wandels Hav the camping sites were determined by latitude in connection with an azimuth at Nakkehoved. On May 5th Nakkehoved was seen for the last time, but not until May 6th was Peary Land sighted. On the voyage across Wandels Hav the connection thus failed a second time. The position of Peary's Cairn is, therefore, also determined by the watch. My determination of the longitude of Peary's Cairn coincides closely with that arrived at by Peary himself; on the other hand the latitude, as observed by me, deviates by a couple of minutes from that given by Peary.

At the great majority of stations the longitude was geometrically determined by azimuth and latitude on the map, but everywhere the watch was used as a means of control. The deviations between the results of the two methods hardly ever exceeded a couple of kilometres and often only amounted to a few hundred metres. One may thus take it for granted that on the two occasions where the azimuth connection failed, and the determination of longitude consequently became exclusively dependent on the watch, no error of practical importance has been introduced into the map. As far as the

[1]) Rekvedøen, the latitude of which was directly observed by myself in 1906, was by Bistrup, in the course of the triangulation work at Dove Bugt, connected by azimuth with Cairn XXIII on Moskusoxefjældene, which cairn was in its turn by means of the network of triangulation connected with the Observatory at Danmarks Havn.

longitude is concerned the particularly good connection with Peary's Cairn further serves to strengthen this supposition.

The sledge trip to Dronning Louises Land in May 1908 (see the map: 1 : 500000, Pl. III).

This voyage, extending over forty-three days (from April 24th to June 5th) was a hand-sledge journey i. e. a sledge journey without the assistance of dogs. The object was among other things the mapping out of Anneksøen, Kofoed Hansens Bræ and the northern part of Dronning Louises Land. During this voyage I used, as in 1907, the chronometer 57203 and watch *K*, the latter as an observation watch and ordinary timepiece. The mean value of the rate throughout the journey was determined by determinations of time in the permanent Observatory on April 22nd, before the departure, and on June 6th, after the return; besides we succeeded in controlling the rate by two determinations of time, taken in the same place on the edge of the inland ice northwest of the Anneksøen, on May 11th, before the ascent on the inland ice, and on May 23rd, after the descent. The result of these four determinations of time were the following:

Place of observation	Date	Interval	Rate in twenty-four hours by the clock	
			57203	Watch *K*
Danmarks Havn	22/IV	45 days	$\div 3^m53^s.3$	$+ 10^s.4$
— —	6/VI			
The edge of the inland ice..	11/V	12 days	$\div 3^m53^s.9$	$+ 9^s.4$
— — — ..	23/V			

In the computation of the difference of longitude between Danmarks Havn and the edge of the inland ice the value $\Delta u = \div 3^m53^s.3$ was used. The two values obtained for the difference of longitude are:

The observations 22/IV and 11 V diff. of long. Danmarks Havn—inland ice 11^m53^s,

— 23/V and 6/VI — Danmarks Havn—inland ice 12^m01^s.

The mean of the two values gives $11^m57^s = 2°59'.2$

Danmarks Havn west of Grw. — ..... $18°42'.6$

The edge of the inland ice west of Grw. gives $21°41'.8$.

In the preparation of the map this value was not used, in that from the points XXIII and XIX in Moskusfjældene and Trekroner, determined by triangulation, we succeeded in carrying the deter-

mination of position from Sælsøen through Anneksøen from station to station, by means of latitude and azimuth only. The construction on the map of the position of the station at the edge of the inland ice gives in this manner the longitude 21°42′. This agreement between the two observations is of course greater than might a priori be expected.

For the journey across the inland ice to Ymers Nunatak it was impossible to use the azimuth for the determinations of position, because the only accurately determined points on the coastland, which could be identified, were situated in the northwesterly part of Anneksøeu, and the direction at these points only deviated very little from the east. The azimuth at those could, therefore, only be used as a control of the latitude, which was less valuable. (On the other hand the levelling at these points was of considerable value in determining the altitude of the station). The determination of longitude at the five stations on the inland ice was, therefore, to be based on the watch. A valuable control of the astronomical observations on the inland ice I got by pointing from every station certain points in Dronning Louises Land, in particular the point in the most northerly part of the country, designated by the altitude 1710, a very sharp and clearly defined point on a dark rocky slope. By marking off the stations on the map by means of latitude and longitude and then by drawing the sights at point 1710, it turned out that the five sights came very near to intersecting at one point. An immaterial shifting of a few of the stations was the result of this control.

It might perhaps be thought that also through the levellings at a sharply defined sighting point, such as point 1710, it would be possible to achieve a control. In the following, when I come to deal with the levellings, I will show that the control attained in this way it a very unreliable one.

The Geographical Sketching Survey.

In the foregoing I have already mentioned the astronomical observations constituting the framework of the survey upon which the sketching survey depends. The principles which hold good for astronomical observations under difficult conditions — simple methods and a control of the survey — one also ought to aim at in the course of the sketching surveys. Especially on far-going sledge trips to regions to which one is not going to return, it is likewise of great importance on the journey itself to draw a rough map, based upon a rough computation of the observations. Only in this manner can

one at once gain a tolerably, reliable general view of the value of the material provided and thereby, in turn, get the possibility of being able to remedy existing drawbacks while in the place itself.

The fact that one's physical strength becomes almost exhausted during the day's march may entirely exclude an advantageous choice of stations of observation. One is often forced by the travelling conditions to perform the observations, whilst one's comrades pitch the tent, feed the dogs, cook the food or sleep, and for that reason it is necessary to choose the observation in the immediate vicinity of the camping place. But if one has sufficient time and strength to do so, one should not shirk the effort of a mountain ascent; from one station with a favourable position and high altitude a more reliable and complete material is obtained than from several small stations on the sea ice.

The sketching survey comprises:

The drawing of perspective sketches.

The determination of the bearings at the points to be included in the observations.

Levelling.

Measuring of the distance.

Notes during the journey from station to station.

Map sketching during the journey.

The perspective sketches.

In the eyes of the beginner perspective drawing often looms up as great difficulty, but a few experiments are generally sufficient to persuade one that the difficulties may be surmounted. For beginners I would recommend chequered paper (squares of 1 cm^2). In arctic regions it is practicable to use yellow paper, as the eyes are then less strained than when using white.

The drawing has only to represent the characteristic features of the landscape in fairly correct proportions; but no extreme degree of accuracy is demanded. It may even serve one's purpose to make certain things stand out more clearly in the drawing than they appear in nature, and so in this manner to exclude all doubt, when one has to use the sketch for the later drawing of the map.

When the temperature is low and the terrain intricate, the making of sketches may sometimes be a tedious task, but one must not for that reason reduce the demands on accuracy. In the course of the further preparation of the map doubts often arise as to details, especially in the case of an intricate terrain, and then there is no expedient to clear up the doubt, except the sketches.

When the drawing is finished, one marks off with figures the points at which one desires to make observations.

On Pl. VI are reproduced two of the sketches drawn by Hagen in 1906 and belonging to the Station K III on the top of Rekvedøen in Skærfjorden.

Bearings and levellings.

In the course of the chapter on triangulation, stress has been laid upon the fact that one ought not to mix up the measuring of horizontal and vertical angles, because the accuracy of the measuring of horizontal angles would suffer by it. Considerations of that kind are of no value in the geographical sketching survey. One ought, as mentioned above, to take the greatest possible care in the determination of the position of the observation stations; but in return one may, as a rule, permit oneself certain facilities as regards the sketching survey, without running the risk of the map becoming in that way less accurate. I am thinking of the following facilities:

Each single angle is only measured once.

The horizontal and vertical angles are measured simultaneously, in which manner one observation at each point is saved. The reading is made in whole minutes and only takes place on the one vernier.

The level is not read. This last measure, however, does not exempt one from keeping an eye on the level. On the contrary. If the bubble of a well-verified level shifts so much from the middle of the tube that the level correction would amount to more than a minute, the levelling screws must be re-adjusted.

By making use of the above-mentioned simplifications a good deal of time is saved, which may be of great importance, when one is tired or when the weather conditions are unfavourable, but it will appear that one has at the same time dispensed with control as regards errors of reading. It is, therefore, necessary to concentrate one's attention on this point.

When at the measuring of vertical angles one does not reverse the telescope but contents oneself with one pointing, the zenith point correction must be known, and as the latter, in consequence of the rough handling on sledge trips, may have altered on the journey from one camping site to another, it must be determined on each separate occasion.

In order to make sure that the position of the instrument has not altered in any perceptible degree during the observation one must, to conclude, once more sight the first point observed.

It was, however, only in places where the stations were situated in such a manner as to control each other mutually that I dared to make use of the above-mentioned simplifications. I shall later on give an extract from my diary from the journey in Peary Land, from which it will appear that on that occasion I have generally thought it necessary to set to work with somewhat greater care.

Below I shall give measurements in detail from Station K III, Rekvedøen, corresponding to the sketches on Pl. VI. Here I made the observation in the aforesaid simplified manner. The station, which lies on the small hill on the island indicated in the map by the figure of altitude 160 is situated at 77°20′.6 northern latitude and 19°02′ west of Grw. The barometric measuring to be mentioned in the following is for the sake of completeness also included here.

The three aneroids are designated by b_1, b_2 and b_3; the reading is in milimetres. The temperature in centigrade is designated t.

Station K III, Rekvedøen, 19/VIII 1906.

Measuring of heigths.

The altitude of the camping site above the level of the sea 2 m.

	Ascent		Descent	
	At the tent	On the top	On the top	At the tent
b_1	761.6	746.5	743.6	759.2
b_2	765.8	750.0	746.1	762.8
b_3	762.6	748.0	744.1	760.3
t	+ 2.6	+ 0.5	÷ 1.8	÷ 0.5

Bearings (As a result of the determination of azimuth the meridian point of the circle was found to be 86°14′).

No.	Designation of sighting point	Horizontal circle	Vertical circle	Compass
1	Point at Vaagesund	346°12′	264°25′	
2 a	Station K I, the cairn on Rosio	11 15.5	269 24	Checked
2 b	Kap Marie Valdemar	17 51	269 20.5	151°.5
3	Point, coast east of Vaagesund	21 40	268 55.5	
4	Small bay in Vaagesund	21 40	265 01	
5	The coast east of Vaagesund	25 09	268 33	
6	Creek east of Vaagesund	39 30	267 10.5	
7	Mountain (St. K. I, No. 14)	c. 54 22	271 59	
8	Peak east of Vaagesund	55 08	270 40	
9	Tangent to mountain slope	85 09	271 15	
10	Coast, south side of Vaagesund	85 09	266 04	
11	Coast, southern bay in Skærfjorden	94 09	269 21	
12	Coast, southern bay in Skærfjorden	101 22	269 21	

No.	Designation of sighting point	Horizontal circle	Vertical circle	Compass
13	The coast south of Vaagesund	101°22′	268°01′	
14	Peak south of Skærfjorden	110 16	270 21.5	
15	Promontory in southernmost bay of Skærfjorden	124 30	269 19	
16	(Deleted)			
17	Peak, distinguished by a notch	159 20	271 05	293°.2
18	West coast of bay	159 20	269 13	
19	Peak	161 39	271 10	
20	Peak	179 34	270 44	
21	West coast of bay	179 34	269 23	
22	Peak	181 02	270 42.5	314.8
23	Point south of Kap Récamier	185 33	269 27	
24	Kap Récamier, the coast	190 34	269 32	
25	Kap Récamier, the peak	194 29	271 03	
26	South tangent to island	197 25	269 36	
27	Kap Récamier, north tangent	196 56	269 32	
28	Peak on island	199 20	270 05	
29	North tangent to island	200 47	269 36	
30	Skerry, south end	203 15	269 35	
31	— north end	204 15	269 35	
32	Island, south end	205 13	269 37	
33	— north end	208 17	269 36	
34	Skerry, south end	207 14	269 29	
35	— north end	207 51	269 29	
36	Skerry, south end	208 28	269 31	
37	— north end	209 17	269 31	
38	South tangent to Joinville Ø	211 12	269 33	
39	Skerry, centre	211 48	269 24	
40	Skerry, centre	213 09	269 24	
41	Skerry, southwest tangent	214 51	269 24.5	
42	— southwest tangent	215 50	269 30	
43	— northeast tangent	216 07	269 30	
44	Skerry, (41), northeast tangent	218 03	269 23.5	
45	Peak on Joinville Ø	221 31	270 16	
46	East tangent to Joinville Ø	222 56	269 34	
47	Hakkemandstoppene	227 20	270 24	
48	Island, west tangent	229 08	269 34	
49	— east tangent	232 14	269 34	
50	Skerry, centre	233 17	269 35	
51	Kap Amèlie, the coast	244 12	269 33	
52	Kap Amélie, the coast	251 43	269 31	
53	Tangent to land northeast of Kap Amélie	272 40	269 34	

Determination of zenith point correction, Δz.

Point 47. Telescope left . 270°23′.6

Telescope right 89 36.4

Sum total.. 360°00′; $\Delta z = 360° \div \frac{(270°23'.6 + 89°36'.4)}{2} = 0.$

The computation will later on be dealt with briefly. In this place I shall only add a few remarks to the observations from Station K III.

The zenith distance measuring (the levelling) is, as far as the hill tops are concerned, to serve for the computation of the altitude; the latter, however, can only be done, when the distance to the top can be determined, which as a rule is only possible in case one succeeds in pointing the same top from another station. As far as the points on the coast are concerned, the zenith distances serve for the computation of the distances on the basis of the altitude of the station; as for this fuller particulars below. The zenith distance is here, where $\Delta z = 0$, equal to 360° ÷ the reading (the angle of depression equal to 270° ÷ the reading).

The readings of the compass were performed on the boussole belonging to the instrument set up during the observation. The object of the three readings was partly to test the boussole, partly to gain a fair idea of the variation.

After the termination of the observation point 2 a, the cairn on Rosio was once more sighted in order to test the unvaried position of the instrument.

By the sighting at point 2 a (Station K I) the two stations K I and K III are connected by means of the azimuth. The altitude of Station K I was 23 m (on the map rounded off to 20). Through the vertical angle at K I one thus gets the means of controlling the altitude of the telescope at K III. The angle of depression at 2 a is 0°36′; the distance between the two stations is measured on the map at 15100 m. The checking computation on the altitude of the telescope at K III is as follows:

The altitude of point 2 a		23 m
15100 tan 0°36′	+	157 -
Refraction and curvature of the earth	÷	14 -
The altitude of the telescope at K III..		166 m

If the altitude of the telescope above the standing place at K III is estimated at 1,2 m. the altitude of the station K III becomes equal to 165 m, which corresponds particularly well with the barometric observation (see p. 303).

The measuring of distances.

Vertical base.

In the geographical survey of a stretch of coast, where one of the principal objects must be the establishing of the coast line itself,

a method often resorted to is to choose the observation stations on coast mountains, to determine the altitude of the station, for instance by means of barometric levelling, and to use this altitude as the basis for distance measuring at points situated along the coast line. This simple and serviceable method, which has, for instance, been widely used in Greenland, has been made the subject of scientific treatment by C. Börgen and R. Copeland, the astronomers of the Germaniaexpedition[1]). On the strength of their researches Börgen and Copeland have further prepared a table as a help to the computation of distances.

In testing the accuracy of the method Börgen and Copeland set up a differential equation which looks as follows:

$$dD = adz + bdH,$$

where D is the distance, z the zenith distance and H the altitude of the telescope above the level of the sea. As an example I shall state that the co-efficients a and b of the differential equation are computed for the distance measuring at a definite coast point from Station Kap Bremen. H is here determined at 1008.3 m, z at 91°06′20″.3; the refraction constant is estimated at 0.2. The differential equation in this case looks as follows:

$$dD = \div 29.48\, dz + 91.21\, dH.$$

After this it is said:

"If the zenith distance is supposed to be encumbered by an error of 10″ and the altitude of the station by an error of 2 m, one will thus by an altitude of 1000 m be able to determine a distance of 66 kilometres, without greater errors in the latter than at most 500 m."

This gives a most misleading idea of the accuracy of the method. The example shows quite clearly that Börgen and Copeland, as sources of errors in the zenith distance, only reckon with the errors due to the measuring operation itself, but pay no attention at all to the variations of the refraction. These may, however, cause errors in the zenith distance of several minutes, so that dz in place of 10″ ought rather to be put at 2′ (see the section on Terrestrial Refraction) in which manner the error in the 66 kilometres, computed in the example, would amount to nearly 4 kilometres.

That one must, in numerous cases, put up with a much greater uncertainty than 2 m in the altitude of the station is also known by everyone who has gone in for practical geographical survey.

[1]) Zweite Deutsche Nordpolfahrt II, Küstenaufnahme mittels Depressionswinkeln, p. 878—883.

In the rarely occuring cases where — for instance on the Germaniaexpedition as well as on the Danmark-Ekspedition — in a smaller field of operations a complete triangulation has been undertaken, in connection with a carefully performed trigonometrical levelling of the stations, the error in the altitude of the stations above the mean sea level will only quite exceptionally amount to 2 m, and yet an uncertainty of 2 m is even here a low estimate, as soon as it comes to using the altitude of the station as the basis of a coast survey. This is partly due to the tidal movement and partly to the fact that tidal pressure ridges and ice foot may produce an "apparent" coast line, which may be several metres higher than the "true" coast line. So at Germania Harbour, where the Germaniaexpedition wintered, I have found an ice foot, the altitude of which above the mean sea level was about 3 m.

On sledge trips the trigonometric levelling of the stations is, however, extremely often either quite out of the question or of such a primitive kind that it may only seem to control a barometric levelling, which according to the circumstances may be encumbered with a very considerable error, for instance of 20 to 30 metres.

It is, however, self-evident that the accuracy of the distance measuring is dependent upon the altitude of the station and is greatest in the most highly situated stations, because here the relative error of altitude, $\frac{dH}{H}$, is generally smallest. Also in this respect the example given by Börgen and Copeland from Kap Bremen is not quite so good as it might be, as an altitude of 1000 m is very rarely met with in stations situated on coast mountains. At all the observation stations of the Danmark-Ekspedition, amounting to nearly 200, this altitude was never reached, even though a couple of times we came very near to it. So also in my survey of the region round Scoresby Sound in 1900 my stations never reached an altitude of 1000 m.

But though one is thus forced to acknowledge that the measuring of distances with the altitude of the station as its basis is, in manifold instances, encumbered with great uncertainty, the method has, however, its indisputable advantages, so that one never ought to omit using it in geographical surveys, where it is possibe to use it, even in the case of very small altitudes of stations, for instance of 50 m. This is among other things due to the fact that in an intricate terrain, for instance within the skerries of Jøkelbugten (the glacier bay) and in Dove Bugt it is impossible to get a general view of things without ascending some mountain. If the terrain is low, even quite a small altitude is of importance, but having ascended the mountain one gets the vertical base and the measuring of the

distance for next to nothing, because the barometric measurement and that of the angles of depression only require a minimum of time. It is true that the measuring of the distance, when the altitude is inconsiderable, becomes most uncertain, but one knows it and can pay sufficient attention to it, not only while drawing the map, but also on the journey itself, in that one looks for the necessary control through a convenient choice of the following station. A control of this kind will, however, only include a few of the points measured at; but one may then, while drawing the map, by examining the distance to the points controlled form an estimate of the error of the distance to the uncontrolled points, computed through the angles of depression.

Particularly at low-lying stations one may run the risk of the coast line, in remote localities, falling under the horizon, though one may not be able to perceive it immediately. If only for this reason, it will in any case be most prudent to level at the horizon.

The dip of the sea horizon thus constitutes a minimum of the values which the angles of depression from the station in question may assume; when one gets near it, the measuring of the distances becomes quite unreliable. (As to the determination of the dip of the sea horizon see pp. 307—308).

In the Jökelbugten, where the highest station was situated at 330 m, whereas the greater part were considerably lower, the method in itself was not very satisfactory; but the travelling conditions in this place did not at all permit of the time-wasting and difficult measuring of the horizontal base. If we had not used distance measuring with a vertical base, we should have been reduced to determine the mutual position of the islands only by means of bearings from the various stations, and it would then have been simply impossible to make head or tail of the complex material, because in numerous cases it only became possible, through the measuring of the distance, to establish what sights were directed from the different stations at the same islands and skerries.

At the measuring of the altitude of stations, one is, as a rule, forced to have recourse to barometric measuring with aneroids, because this method, with a minimum of work, leads to a result which offers a satisfactory guarantee against gross errors. The principles of barometric measuring are, besides in other places, set forth in H. Mohn, Praktisk vejledning til højdemaaling med barometer, Kristiania 1888. The tables to be found in this little book have been used at the computations of the barometric measurings of the expedition.

A more accurate barometric levelling demands simultaneous

readings at the station and at the surface of the sea. This demand one can, as a rule, not satisfy, but one must be content to read off one's barometer at the level of the sea before the ascent and after the descent, as well as at the station after the ascent and before the descent, as indicated in the example on p. 297. In order to make sure against the effect of disturbances in the instrument during the ascent it answers the purpose to use three aneroids.

Examples of the computations will be found in the above-mentioned work of MOHN's. As to the example given on p. 297 a computation corresponding to the accuracy of the observation may be performed in the following manner:

Ascent.

	b_1		b_2		b_3	
	761.6 / 746.5	MOHN table V: 8167.3 / 8007.9	765.8 / 750.0	MOHN table V: 8211.1 / 8045.1	762.6 / 748.0	MOHN table V: 8177.8 / 8023.8
approximate diff. of altitude h_0		159.4		160.0		155.0
temp. corr. $2(+2.6+0.5)\frac{h_0}{1000}$		+1.0		+1.0		+1.0
diff. of altitude		160.4		167.0		156.0

Descent.

	b_1		b_2		b_3	
	759.2 / 743.6	MOHN table V: 8142.2 / 7976.9	762.8 / 746.1	MOHN table V: 8179.9 / 8003.6	760.3 / 744.1	MOHN table V: 8153.8 / 7982.3
approximate diff. of altitude h_0		165.3		176.3		171.5
temp. corr. $2(\div 1.8 \div 0.5)\frac{h_0}{1000}$		$\div$ 0.8		$\div$ 0.8		$\div$ 0.8
diff. of altitude		164.5		175.5		170.7

Mean of the six determinations 165.5
Altitude of the camping site above the level of the sea 2.0
Altitude of telescope ... 167.5

When the barometric measuring is performed as here mentioned, it is in itself not very satisfactory, and gives a greater uncertainty in the distance measured than is desirable. Therefore one also ought to have one's attention directed towards every possibility of improving or at any rate controlling the result. This may, for instance, be done by means of trigonometric levelling at a point, the altitude and distance of which from the station are known. An example of such a particularly successful control is given on p. 299 in levelling from Station K III to Station K I. In the section on terrestrial refraction certain practical hints are given as to the way in which one may, by means of certain meteorological and topographical conditions, form an estimate of the value of a control of this kind. Here I shall only remark that when the distance, at which the levelling takes place, exceeds 30 km, the control often becomes rather valueless, owing to the uncertainty of the refraction.

At times one may, when marking off one's station by means of a cairn after the descent get the opportunity of measuring a small base on the ice, and from the termini of the latter to level the cairn of the station. In the few cases where we have been able to do that, we have generally not only managed to control the result of the barometric measuring of altitudes, but also to improve upon it.

(As to the control of the altitude of the station by measuring the dip of the sea horizon, see p. 308).

As mentioned above Börgen and Copeland have prepared special auxiliary tables to be used at the computation of the distanees. The accuracy with which these tables have been prepared rests, however, on the proved wrong ideas of the accuracy of the whole distance measuring. The tables are therefore unnecessarily elaborate and unpractical in use. In the following I am going to give a simpler and quicker method of computation.

The general formula of the difference of altitude between two points

$$H \div H_0 = D \cot z + \frac{1 \div k}{2R} D^2$$

can with a trifling modification be used for this computation. H_0 is here the altitude of the telescope above the level of the sea; H — the altitude of the coast point — is equal to zero. D is the distance, k the refraction constant, R the radius of curvature of the earth. If the zenith distance z is put $= 90° + v$, where v is the depression angle, the formula may be altered to

$$D \tan v = H_0 + \frac{1 \div k}{2R} D^2.$$

For the computation we made use of a four-placed table of the numeric values of the tangent function[1]) as well as the small table below of the term $\frac{1 \div k}{2R} D^2$[2]). This latter table is computed for the co-efficient of refraction $k = 0.2$ and for $R = \sqrt{MN}$, where M and N are the radius of curvature of the meridian and of the normal segment to that in 78°30′. D is expressed in kilometres, the other two colums in metres.

[1]) A table of this kind is found in: Th. Albrecht, Vierstellige Logarithmentafel, Leipzig, Verlag von Wilhelm Engelmann, 1894.

[2]) It rather often happens when computing vertical angles that one has to use the correction of refraction and curvature of the earth — the term $\frac{1 \div k}{2R} D^2$ — corresponding to values of D which exceed 40 km. The correction is then easily computed from the table, when it is borne in mind that it is proportionate to the square of the distance.

D (Km)	$\frac{1 \div k}{2R} D^2$ (Metre)	Diff.	D (Km)	$\frac{1 \div k}{2R} D^2$ (Metre)	Diff.
1	0.1	0.2	21	27.8	2.6
2	0.3	0.3	22	30.4	2.9
3	0.6	0.4	23	33.3	2.9
4	1.0	0.6	24	36.2	3.1
5	1.6	0.7	25	39.3	3.2
6	2.3	0.8	26	42.5	3.4
7	3.1	0.9	27	45.9	3.4
8	4.0	1.1	28	49.3	3.6
9	5.1	1.2	29	52.9	3.7
10	6.3	1.3	30	56.6	3.8
11	7.6	1.4	31	60.4	4.0
12	9.0	1.6	32	64.4	4.1
13	10.6	1.7	33	68.5	4.2
14	12.3	1.9	34	72.7	4.3
15	14.2	1.9	35	77.0	4.5
16	16.1	2.1	36	81.5	4.6
17	18.2	2.2	37	86.1	4.7
18	20.4	2.3	38	90.8	4.9
19	22.7	2.5	39	95.7	4.9
20	25.2		40	100.6	

The computation of the distance which is performed with the utmost simplicity and very quickly by means of the engineer's scale becomes indirect. One begins by computing an approximate value of D, i. e. $D_1 = \frac{H_0}{\tan v}$, and after that one selects from the table at an estimate and rounding off upwards the correction $\frac{1 \div k}{2R} D_1^2$. In this manner one gets a fictitious altitude $H_1 = H_0 + \frac{1 \div k}{2R} D^2_1$ and now computes $D_2 = \frac{H_1}{\tan v}$. From the table one takes again at an estimate $\frac{1 \div k}{2R} D_2^2$ in which manner one gets a new fictitious altitude $H_2 = H_0 + \frac{1 \div k}{2R} D_2^2$ and so on. As a rule one has already at the second attempt found the true distance, which appears during the computation from the fact that the fictitious altitude of the station, after the correction for refraction and curvature of the earth, remains unchanged in whole metres.

Example 1. $H = 450$ m; $v = 1°56'$.

$\tan v = 0.0337$. The index of the sliding rule of the engineer's scale is put at 337. The division 450 on the fixed rule then indicates $D_1 = 13.34$ on the sliding rule.

The correction corresponding to D_1, i. e. $\frac{1 \div k}{2R} D_1^2$ is calculated (rounded off upwards) at 12 m. Thus $H_1 = 462$.

The engineer's scale is still lying untouched with index at 337.

Therefore one promptly reads off on the sliding rule $D_2 = 13.7$ km corresponding to division 462 on the fixed rule. The correction for refraction and curvature of the earth now again becomes 12 m (more accurately 11.7 m). Thus $D = D_2 = 13.7$ km.

One will see that at the computation it is not necessary to record. When the index is put at the division corresponding to $\tan v$ one has the distance looked for in a fraction of a minute.

Example 2. In the quite extraordinary case from Kap Bremen (mentioned on p. 300) the altitude is given as 1008.3 m, the zenith distance as 91°06′20″.3. As one is here dealing with distances of more than 40 km, the simplest way to find the correction for refraction and the curvature of the earth is to take the correction for half the distance and afterwards multiply the latter by 4.

If H is put 1008 m, $v = 1°06'.3$, $\tan v = 0.0193$, the index is placed on 193, after which the computation becomes as follows:

$H_0 = 1008$ m; $D_1 = 52$ km; Refr. and curv. of the earth $= 4 \times 43 = 172$ m.
$H_1 = 1180$ - ; $D_2 = 61$ - ; — — — $= 4 \times 60 = 240$ -
$H_2 = 1248$ - ; $D_3 = 65$ - ; — — — $= 4 \times 67 = 268$ -
$H_3 = 1276$ - ; $D_4 = 66$ - ; — — — $= 4 \times 69 = 276$ -
$H_4 = 1284$ - ; $D_5 = 66.5$ - ; — — — $= 4 \times 70 = 280$ -
$H_5 = 1288$ - ; $D_6 = 66.8$ - ; — — — $= 4 \times 70.2 = 281$ -
$H_6 = 1289$ - ; $D_7 = 66.8$ - ;

$$D = D_6 = 66.8 \text{ km}.$$

In the last mentioned example it has been necessary to compute six different fictitious altitudes; but it will appear that one might have saved a good deal of the work. The first computation, by which D_1 is determined, only takes place in order that one may get an approximate idea of the distance looked for, and through it of the fictitious altitude corresponding to the distance sought. As it is given that $D > D_1$, it was not necessary to select the correction of refraction and curvature of the earth, corresponding to D_1, but starting from the knowledge of the value D_1 one might immediately have tried to estimate at the value D and after that to have taken the approximate correction of refraction and curvature of the earth corresponding to the estimated value of D. When, as in the case of the Danmark-Ekspedition, the object is to compute several thousand distances, one attains considerable skill in forming an immediate and pretty correct estimate of the distance sought. It evidently does not seem to matter that one flies too high in making an estimate of this kind.

The last example I will compute once more to show how the computation would presumably be performed by a trained computator.

$$H_0 = 1008\text{ m},\ v = 1°06'.3,\ \tan v = 0.0193.$$

H_0=1008 m; D_1=52 km; D estimated at 70 km; Refr. and curv. of the earth 4×77 = 308
H_1=1316 - ; D_2=68 - ; D — 67 - ; — — — 4×70.6=282
H_2=1290 - ; D_3=66.9 - ;

$$D = D_3 = 66.9\text{ km}.$$

That the first estimated value of 70 km is too great immediately appears from the fact that D_2 becomes smaller than 70 i. e. 68 km. The value of D looked for must therefore also necessarily be smaller than 68 km. As the differences between the D's become smaller and smaller, according as the computation progresses, the value looked for must, however, be greater than $68 \div 2 = 66$ km. Therefore it is only natural that in the second experiment one should try the value 67 as shown above.

That the two results 66.8 km and 66.9 km differ by 0.1 is due to the imperfection of the engineer's scale. But this little inaccuracy is of course without any practical importance whatsoever.

Before leaving the chapter on the measuring of distances by means of the vertical base, I shall mention the importance of performing special levellings for the determination of the dip of the sea horizon.

During a coast survey, where one has nearly always the opportunity of seeing the sea horizon, one ought not to omit levelling the latter, both at the beginning and the termination of the survey performed from a station and, if possible, in two directions. The levelling at the sea horizon ought to be performed both with "telescope right" and "telescope left", and by reading the level. In this manner one gets the means of computing the co-efficient of refraction or of eliminating the latter from the computation of the distance.

One gets:

$$h = \frac{R}{2(1 \div k)} \tan^2 \alpha$$

where h is the altitude of the telescope above the level of the sea, and α is the dip of the sea horizon.

If the altitude of the telescope has, in another way, been determined at H_0, one must get $h = H_0$ or

$$\frac{1 \div k}{2R} = \frac{\tan^2 \alpha}{4 H_0}$$

By inserting in the equation mentioned on p. 304

$$D \tan v = H_0 + \frac{1 \div k}{2R} D^2$$

this term is rounded off into

$$D \tan v = H_0 + \frac{\tan^2 \alpha}{4 H_0} D^2.$$

The term $\frac{\tan^2 \alpha}{4 H_0} D^2$ is tabulated for the argument D in a similar manner as shown on p. 305 for the term $\frac{1 \div k}{2 R} D^2$, after which the computation of the distances is performed on the engineer's scale as mentioned above.

The importance of a careful levelling at the sea horizon is thus to be found in the fact that in this manner it becomes possible to eliminate the strongly varying co-efficient of refraction (see, however, also the remark on p. 302). The dip of the sea horizon is, on the other hand, not so well suited for the determination of the altitude of the telescope above the level of the sea, when k is not known beforehand, which by the way will never occur in practice.

By differentiating

$$h = \frac{R}{2(1 \div k)} \tan^2 \alpha$$

we get

$$dh = \frac{R}{2(1 \div k)^2} \tan^2 \alpha \, dk = \frac{h}{1 \div k} dk.$$

If for altitudes between 500 and 1000 m we put $k = 0.15$
— — — 100 - 500 - — $k = 0.2$
— — — 20 - 100 - — $k = 0.3$

it may be supposed that dk as far as the greater altitudes are concerned will rarely exceed 0.1, whereas dk as far as the lesser altitudes are concerned may easily become as high as 0.2. If one further takes into consideration that the error of the altitude determined by α is proportionate to $\frac{h}{1 \div k}$ it will quickly be realized that this manner of determining the altitude will generally, as far as certainty is concerned, be considerably inferior to the above-mentioned primitive barometric measurement.

In those cases where every other form of the measuring of altitudes fails, or where one wishes to apply a control to the altitude determined in a different way, it may, however, be necessary or justifiable to compute the altitude by means of the dip of the sea horizon.

For this purpose, one may, as far as North Greenland is concerned, make use of the following simple term:

For altitudes between 500 and 1000 m ($k = 0.15$)
$h = 0.318 \tan^2 \alpha$
— — between 100 and 500 m ($k = 0.2$)
$h = 0.338 \tan^2 \alpha$
— — between 20 and 100 m ($k = 0.3$)
$h = 0.386 \tan^2 \alpha$.

Horizontal base.

However great the importance of the use of the vertical base may be in the geographical survey, it is, however, sharply limited by reason of the fact that it is only suitable for determining the border line between land and water. Besides it is a necessary condition of the measuring of distances by depression angles that one is able to ascend a mountain, which is not always possible. Therefore, not only during the inland voyages, but also now and then during the coast survey it becomes necessary to use the horizontal base.

On sledge journeys the expedition made use of a measuring tape for the direct measuring of horizontal distances. On a few occasions, where the measuring tape could not be used, either on account of the nature of the terrain, or because the labour would have been insuperable, we made use of Souchier's distance meter (see p. 259).

Our measuring tape was a small steel tape, 5 metres long and provided with a leather case; it could be carried conveniently in a pocket. Throughout the whole of its length it was divided into centimetres, and besides the first decimetre was divided into millimetres. We did not use plugs or the like. In order to use the measuring tape level, fairly firm ground was requisite, preferably a solid snow-field or ice bare of snow. Before measuring we paced the base and marked its termini with tent poles. During the measuring the man in front marked off the end of every length of the tape by making a notch with a knife in the snow or ice, and at the same time he wrote the number of the tape length in the snow, alongside the notch, and called out the number so loudly that the man walking behind could hear it, and thus check it. A precaution of this kind is necessary, as otherwise there will almost invariably arise a doubt as to the number of the tape lengths. An advantage gained by this precaution was that we were only obliged to measure the bases once throughout their entire length.

The length of the directly measured bases rarely exceeded sixty tape lengths, or 360 m, which was, as a rule, sufficient when it was simply a question of measuring the altitude and mutual position of a few neighbouring points. Very often, however, we extended our base line into a base triangle by means of a small triangulation, either because the terrain was unfavourable for measuring a sufficiently long base in the direction desired, or because the establishing of the various points in the terrain necessitated a third position of the instrument.

As an example I shall quote the measuring from Station III on

Annekssøen (annex lake) performed during the hand sledge trip to Dronning Louises Land in May 1908. Here a base line bc = 190.43 m was measured by means of the measuring tape. In a triangle abc this length was transferred to the sides ab and ac, by means of measuring at all the three points. The objects — tent poles — were only pointed once, and only one vernier was used. The result was

$\angle a$	20°34′	According to this ab is computed = 474 m
$\angle b$	98 37	ac — = 536 -
$\angle c$	60 51	
Sum total	180°02′	

The circumstance that the error in the sum of the angle is so small, is not accidental, but is explained by the fact that the instrument was very carefully centred, by means of the plumb, above the hole in the snow indicating the position of the temporarily removed tent pole.

When, as in the example quoted, one permits oneself the facility of only pointing the objects once, one commits an error, in consequence of the eccentricity of the telescope and the unequal lengths of the sides of the triangles. An estimate will, however, prove that the error is in this case without any practical importance. (The eccentricity of the telescope = about 4 cm).

It is evident that with a base of a few hundred metres one can only establish points within a distance of a few kilometres. A distance of twenty times the length of the base ought to be a limit which should not be exceeded.

On hand sledge trips the length of the march seldom exceeds 15 kilometres a day. If one is here so careful as to mark off one's stations — or an accurately determined point in the neigbourhood of the station — with an easily visible cairn, one will, as a rule, be able to establish quite a solid connection between the stations, and the use of the horizontal base may then lead to a result, which is both more reliable and fuller than the one to be got through a vertical base.

Notes made during the journey.

On the journeys made with dog sledges, where the marches often exceeded 40 kilometres a day, and where in a few cases we might cover more than twice that distance in the course of a single day, it could not be avoided that the observation stations now and then came to be so far removed and were so badly situated in relation to one another, that certain errors in the map were un-

avoidable, if in the preparation of the latter one had absolutely nothing to go upon but the observations from the stations. It was, therefore, necessary during the ride from camping site to camping site to make notes as regards the peculiarities of the ground covered, so that in this way one got the means to rectify the deficiencies of the observations made from the stations.

It is thus first and foremost an absolute necessity during the sledge journey to have easy access to one's pocket book.

On this very point I have often been met with the objection that the pocket book is too valuable to permit one's running the risk of losing it, and that it ought to be particularly well packed on the sledge. It is a well-known fact that during the sometimes rather rough work of driving the dogs one is very liable to drop those very things, which during the drive one alternately carries on one's person or perhaps places on the sledge, especially one's wraps (wind-proof garments), and on the other hand it is practically necessary to keep the pocket book in one's outside clothing, should one want to be able to get at it at any time. Therefore, I have seen people, in several cases, pack their pocket books in such a manner that they could only get at them when arriving at the camping site; trusting that for one day they might rely on their memories, and that they might enter the necessary remarks in the journal, after the march was done.

This, however, will not do. One ought to be able to take good care of one's pocket book, even when carrying it in one's outer clothing. Nor have I in a single instance known a sledge driver to loose his pocket book during the drive, whereas I have often known him to lose his whip, mittens, wind-proof garments and similar things, may, even boxes of provisions, without discovering their loss till long afterwards.

The notes are mainly limited to an indication of courses and distances, to a few primitive bearings, to notes concerning peculiarities in the coast line etc. Examples of this may be found in the subsequent extract from my diary.

On the Danmark-Ekspedition I always carried a small pocket compass, but it was never used, because I preferred to go by the sun (in exceptional cases also by the stars) in connection with my watch. Therefore I can say nothing of the practicability of a compass[1]). As one always knows the clock correction to apparent time

[1]) On Peary Land in 1907 I have during a snowstorm proved by means of the compass that we were taking a wrong course. At that time we drove, Eskimo fashion, by the direction of the wind and by the sastrugi of the snow. Wind and sastrugi, however, changed their direction with the course of the mountains

within a few minutes, one may with sufficient exactitude determine one's course by the sun. In order to achieve as great accuracy as possible in the bearings, I have often drawn a compass card in the snow and taken my bearings from it.

The distances we determined by the hodometer (see p. 260). In favourable circumstances and on snow where the going was good, the indications of the counter were to be reduced by nearly 2 %; in unfavourable conditions and particularly in pack ice the reduction might amount to as much as 10 %, or perhaps even more. On smooth glare ice the hodometer might indicate 10 %—20 % too little. Add to this that under difficult circumstances it was often damaged to such an extent that it could only be repaired in camp. The hodometer is thus a very unreliable distance measurer, when one is travelling on sea ice. Nevertheless the measuring of distances by means of the hodometer serves as a support when preparing the maps; therefore the journal ought not only to contain an indication of the hodometer distances, but also to give a valuation of them, as an estimate based upon experience. Several examples of such a valuation will be found in the subsequent extract from my diary.

Map sketching during the voyage.

Before starting on the sledge journey to Peary Land in 1907, I had drawn a network of meridians and parallels, within the limits of which I thought that our route would lie. On this network which was drawn to the scale 1 : 2000000 we intended to mark off roughly the whole of the distance covered. The object of this map was, among other things, already on the outward journey to obtain the best general view available of the various cartographic tasks of the expedition, so that they might be assigned to the various sledge parties, as they turned back and started on their homeward journey.

During the journey north in 1907 I myself made all the observations, and according to these I made, day by day, the general map of the distance covered. The map proved excellently adapted for its purpose. On the basis of it instructions were given to Bistrup and Thostrup as regards the cartographic tasks, which they were to

along the coast, and we consequently overshot the depot, which we desired to reach, by several kilometres. Had we relied on the compass, we should, in all probability, have arrived at the depot.

On Vatnajökull in 1904, after a snowstorm which had completely effaced our tracks, I have found my tent in a dense fog, though I had been about twenty kilometres away from it. That time I steered by a pocket compass, but besides I was very materially guided by certain peculiarities in the surface of the glacier.

perform on their journey in a southern direction from the Mallemuk-fjældet (89°09′) and Amdrup's Land (80°43′).

This general map, however, also played a great part in another direction, inasmuch as it saved us the trouble of computing the determinations of time during the journey itself, because on this map we were able to determine our position by construction through azimuth and latitude.

The interest which all my comrades took in my map sketching, according as it grew on paper, day by day, made me realize that it also was of a more general importance. This instantaneous and intelligible result of our laborious journey gave us all the immediate feeling that we were serving a useful purpose, as long as we came to new regions and saw what no one had ever seen before. It stimulated us and imbued us with a strong desire, not only to penetrate further north, but also, during the return journey, to be able to fill up the numerous gaps in the sketch, which were an inevitable consequence of our forced journey in a northern direction.

Map of the single tracts.

Whereas the general maps may be of importance on very long journeys, it will, I suppose, be practicable as a general rule to sketch a map on a larger scale, also in the case of journeys extending over a shorter period. The means required for this purpose are few and simple: compasses, a pencil, chequered paper and a protractor, which latter may also be used as a rule. Perhaps it may also be expedient to use a logarithm table or an engineer's scale; however, for my part, I never found occasion to do so on the Danmark-Ekspedition.

It is of no use to carry a carefully drawn geographically network. The squares in the paper serve as a network, in that one only takes care that the proportion between minutes of latitude and longitude at a rough approximation becomes like $\frac{1}{\cos \varphi}$. In my sketch map from Peary Land (see Plate VII), extending from 82° to 83°30′ one degree of longitude occupies three squares, whereas a degree of latitude covers twenty. Here the proportion $\frac{1}{\cos \varphi}$ is estimated at $\frac{20}{3}$ which in reality corresponds to φ = about 81°30′. It was the purely practical circumstance of my thus getting three degrees of latitude on each square, which contributed towards the establishing of the proportion $\frac{20}{3}$; but I am quite willing to admit that it would have been still better, if I had chosen the proportion $\frac{24}{3}$ corresponding to φ = about 82°50′, in which manner two squares would here have stood for five minutes of latitude.

It will at once be evident that this arbitrary projection is a modification of Mercator's conform cylindrical projection, and comes so near to the latter, that on the journey itself one may waive all scruples as regards the difference.

The correction from azimuth to rhumb line need not be taken into consideration on the journey.

Extract from Koch's diary on Peary Land.[1])

May 1907.

The object of this extract from my diary is, by publishing in full the original cartographical material from a limited field, to throw light upon what has been said in the foregoing about the geographical survey of the Danmark-Ekspedition. But at the same time I wish to enable my readers fully to appreciate the work done, and for that purpose it is necessary not only to publish the cartographical material proper, but also to give a picture of the conditions, under which the material was procured. For these reasons I have thought it most correct to give a certain part of my diary in extenso.

The reason for my choosing to publish the cartographical material from the east coast of Peary Land, is that the material has a special interest, owing to the fact that the country is very difficult of access. It is not improbable that centuries may pass, before its shores are again invaded by the foot of man.

I give the diary exactly as it was written, without correcting the language. From the phraseology itself it will, therefore, be easy enough to distinguish the short notes jotted down on the march from the more consecutive description written in the tent. The names used in the diary correspond to those of the sketch map made during the voyage (see Pl. VII); but they have been, in a great measure, altered during the process of preparing the final map. In my quotations from the diary I have filled in the headings of the observation tables; this I have, of course, not done in the original.

The sketch map (Pl. VII) has naturally been a good deal knocked about. The route which is only in part entered in it, is difficult to follow. Neither do the observation stations appear clearly on the sketch map. On the finished map (Pl. IV) it will be easy enough to follow the route and find the observation stations, here indicated with a *K* with a date affixed.

My sledge party consisted of Aage Bertelsen, the artist, the Eskimo Tobias Gabrielsen and myself. We drove three sledges, and

[1]) In Medd. om Grønl. XLI, p. 124 and the following Capt. Amdrup has given a report of my voyage to Peary Land in 1907.

our teams consisted of twenty-five dogs. When on May 1st we started from Nakkehoved in a northwesterly direction across Wandels Hav in order to look for Peary Land, our provisions consisted of:

Men's provisions for	15	days
Dogs' feed -	14	—
Petroleum -	25	—

With these supplies we might hope to reach Peary Land and back again to the depots laid out on the east coast of Kronprins Christians Land. During our stay in Peary Land we should mainly have to live on game.

On May 6th we arrived, overworked and with starved and worn-out dogs, at the observation station K 6/5 (Pl. IV). Here the measuring of Peary Land was begun.

(Extract of diary from 5/V, evening).

Started at 9.10 p. m. 5/V

Began by passing a big pressure-ridge which gave us a good deal of trouble. TOBIAS broke a sledge pole. 2 photographs. It took us about an hour to advance the first 30 metres. The pack ice continued, it is true, and though it was no longer of the worst kind, it was still sufficiently fatiguing and troublesome. Advanced very slowly and damaged now one little thing, now another. Broke the wooden crutch which holds the wheel of the hodometer, and consequently had to stop the measuring of the distance. The dogs very played out and feeble. Towards 1 o'clock we had at last got 6/V through the pack ice, and now continued in the direction of the still remote Peary Land at an extremely slow pace, but over smooth and firm snow — the best going possible. With fresh dogs we might have sat on the sledges and driven 10 km per hour: now we walked beside the sledges and only advanced 4 km per hour. In particular TOBIAS' dogs were very tired, so he asked to be permitted to lead with BERTELSEN'S strong bastard team, but failed altogether in the attempt. BERTELSEN'S team was not to be driven to lead. Then I began to lead with my team, and with fair success. Stopped at 7 a. m., after ten hours' march.

At the beginning of the march the wind was a feeble WSW. Thick haze, nearly fog. At times the land disappeared altogether from our sight. Later on the wind shifted suddenly to NW; still extremely feeble. The cover of clouds varied from 2—4, stratus and cumulo-stratus in the northern sky. As soon as we had camped, the wind freshened to degree of velocity 1.

Determination of latitude, 6/V 07, $\Omega_{,,}$ $b = 770.0$, $t = \div 13.8$. On the ice in Independence Sund, 5 to 10 km from the south coast of Peary Land[1]).

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
11h34m00s	293°38′.8	39′.1	12.5	7.3	11h36m25s	66°21′.6	22′.6	3.6	8.8
39 00	39.1	39.5	12.0	6.8	40 50	21.2	22.2	6.3	11.7
42 55	39.2	39.6	11.5	6.2	44 35	21.1	22.1	3.7	8.8
46 45	39.2	39.6	11.5	6.3	48 45	21.0	22.0	3.0	8.3
50 45	39.2	39.5	12.0	6.7	53 10	21.1	22.1	3.0	8.2
55 00	39.1	39.4	11.6	6.2	57 00	21.2	22.2	3.0	8.2

426 21.5
293 39.4
132 42.1

$z = 66\ 21.1$
$\rho = \div\ 15.9$
$r = +\ 2.1$
$\delta = +16\ 18.1$

$\varphi = 82°25'.4$[2])

Wind 2 of N (5 à 6 m); quite light snow drift; cover of clouds 1 à 2, stratus and cirrus; clear air.

At 1 p. m. the wind subsided gradually. At 9 p. m. it was nearly calm. At the same time the direction became more westerly; perhaps due west. The sky became overcast, the sun disappeared, so that there was no determination for time at 6 p. m. From 9 p. m. the stratum of clouds (perhaps alto-cumulus — I lay in the sleeping bag, and only now and then peeped through the tent opening) began to disperse. It cleared up in NW. At 10 p. m. the sun appeared.

During our sleep to-day the dogs have, in spite of the Brönlund sledge arrangements, succeeded in eating seven sledge lashings and quite a new front rope. The meal given to them at the end of the march had been rather scanty, consisting of three pemmican cakes and the dog bitten to death by its comrades.

7/V Commenced the measuring of Peary Land at midnight. Calm: cover of clouds 2; stratus, clear, calm air. We lay on the ice about 5 to 7 km from land[1]), and after the observation we made ready to deposit the provisions, dogs' feed and the goods which we did not intend to take north.

[1]) The distance to the nearest land was in reality about 16 km.

[2]) cf. calculation by estimate, as it should be done p. 265.

We took with us dogs' feed for six days (pemmican and a tin of greaves) provisions for nearly eight days, spirit and petroleum for about nine days, such odds and ends of our private property as we could carry in our sleeping bags and finally a good deal of ammunition. If only the musk oxen and hares would be kind enough to present themselves in front of our rifle barrels; otherwise we should be hard put to it to reach the most northerly point of Greenland, even with the best of sledding. The dogs are terribly weak.

Fig. 41. Brönlund's arrangement to prevent the dogs from eating the sledge lashings etc.

Departure 4 a. m.

Wind 0—1, variable from N to W. Cover of clouds 3, stratus.

Made rather good progress with the easy sledding. At 7.20 a. m. we had made 16 km, and still seemed to be rather far away from land. Consequently we stopped and took observations at a station. (Determinations of time, azimuth, bearings). Continued at 8.20 a. m. Reached land at 9 a. m. after 18 km in all. A level sandy and gravelled beach with shells and plants. Along the beach new ice over old; apparently excellent sledding in south west along the coast. Met at once a covey of snow bunting, about six in number.

28 km. The cranium and bones of a musk ox. Large erratic blocks and gray fine-grained granite.

Four musk oxen, cows with two calves. The two cows had

Peary Land, Station I, night 6—7/V 07.

On the ice; $\varphi = 82°25'.4$; l = about 21° w. of Grw. (Bertelsen's sketches[1]) from camping site 6—7/V 07).

Chron. 57203 $2^h20^m00^s$ $2^h20^m30^s$

Watch K $12^h21^m43^s.6$ $12^h22^m13^s.6$

Determination of azimuth, midnight 6—7/V; ⏀; $b = 771.8$; $t = \div 11.0$

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telesc. left . . . . . $11^h58^m56^s$	278°43'.2	43'.8	11.6	6.1	66°17'	230°.1	N 3° E
Telesc. right 12 00 39.5	81 17.1	17.8	3.6	9.0	66 45	230.1	Variation = 47°
Objects in the terrain:							
1. Tangent to island[1]) in south					271°22'		S 28 W
2. — — —					275 47		S 32 W
3. Tangent to land	The tangent nearly ⊥ the coast				312 07		S 69 W
4. Rounding[2]) in coast					322 14		S 79 W
5. The coast below hummock					337 43		
6. — — —					343 09		
7. Mountain	270°33.0	33.7	12.4	7.0	358 26	162.3	N 65 W
	89 28.0	28.6	3.0	8.3			
8. Mountain	270 42.5	43.4	12.3	7.0	3 52		N 59 W
	89 17.5	18.5	3.0	8.3			
9. Mountain	270 43.0	43.9	12.4	7.0	4 57		N 58 W
	89 17.7	18.5	2.8	8.0			
10. Mountain	270 59.5	60.1	12.3	6.9	15 37		N 47 W
	89 01.5	2.6	2.8	8.0			
11. Foot of mountain					14 22	178.2	N 48 W
12. — - —					20 28		N 42 W
13. Mountain in background . .	270 53.8	54.3	12.3	6.9	22 12		N 40 W
	89 07.6	08.4	3.0	8.3			
14. Mountain	270 53.6	53.9	11.8	6.2	26 31		N 36 W
	89 07.8	08.4	2.8	8.1			
15. Foot of mountain					27 19		N 35 W
16. Mountain[3])					27 37		N 35 W
17. Station[4])	270 16.6	17.1	12.0	6.3	35 58	199.9	N 27 W
	89 44.3	44.9	3.0	8.4			
18. Tangent to coast[5])					42 55		N 20 W

[1]) Kap Rigsdagea at Danmarks Fjord.
[2]) Kap Kjobenhavn.
[3]) Kap Henry Parish.
[4]) Here a station was contemplated, but the idea was not carried out.
[5]) Kap Ejler Rasmussen.

unborn fætus, which seemed nearly fully developed, with hairy skins and hoofs. The one measured 73 cm, the other 67 cm from muzzle to tail. The eyes of the former were open. Neither of the two cows with calves had milk in their udders; this was, on the other hand,

[1]) See Fig. 42.

Peary Land, Station II. On the ice (see BERTELSEN's sketch from St. I[1])). Determination of time on 7/V, forenoon, ☉, b = 773.0, t = ÷ 13. On the ice 15.8 km ÷ 1 % hodom. dist. from St. I in direction of Point 16 (not 17)

Chron. 57203 $9^h40^m00^s$ $9^h40^m30^s$
Watch K 7 40 32.2 7 41 03.0

Telescope left					Telescope right				
Watch K	Vernier		Level		Watch K	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$7^h44^m31^s$	289°50'.7	51'.0	11.1	6.1	$7^h45^m32^s.5$	70°09'.0	09'.4	4.0	9.0
46 33	53.9	54.4	8.9	3.9	47 38	05.7	06.0	5.8	10.5
48 39.5	57.5	58.0	9.0	4.0	49 46	01.8	02.2	6.0	11.0

Determination of azimuth, 7/V, forenoon, ⊕, b = 773.0, t = ÷ 13.

Watch K	Vertical circle Vernier		Level		Horizontal circle	Azimuth
	A	B	Obs.	Obj.		
Telesc. left .. $7^h50^m39^s.5$	290°00'.4	01'.1	9.0	4.0	289°13'	S 62 E
Telesc. right . 52 00	69 58.2	58.6	5.6	10.6	289 37	
Point in the terrain						
1/I, uncertain.....					8°20'	S 17 W
Tangent towards SW...	nearly	3/I			31 16	S 40 W
4/I....					36 23	S 45 W
7/I.....	270°51'.6	51'.7	8.0	3.0	86 33	N 85 W
	80 10.6	11.0	7.5	12.5		
8/I.....	271 04.1	04.5	8.0	3.0	97 12	N 74 W
	88 58.0	58.6	7.5	12.5		
9/I.....	271 03.9	04.4	8.5	3.5	99 35	N 72 W
	88 57.9	58.4	7.5	12.5		
10/I.....	271 35.2	35.5	9.0	4.0	113 33	N 58 W
	88 27.9	28.3	7.9	12.9		
11/I.....					105 29	N 66 W
12/I.....					117 46	N 54 W
14/I.....	271 27.7	28.4	11.0	6.0	130 35	N 41 W
	88 33.3	33.9	8.0	13.0		
15/I.....					131 40	N 40 W
17/I.....	271 08.6	09.0	11.0	6.0	155 23	N 16 W
	88 53.0	53.6	8.0	13.0		
Tangent towards north to headland					213 43	N 42 E

the case with the other two. One of the live calves was immediately torn to pieces by the dogs; the other one measured 63 cm from tail to crown, 83 cm to the muzzle.

[1]) See Fig. 42.

Later on when we arrived with the sledges, an ubik (snow owl) flew across the carcases of the musk oxen.

Already far out to sea we had been able to see that the rather low foreland was in a great measure covered with snow, whereas the mountains seemed in part bare of snow. As we approached land on the southern side of Herlufsholms Næs[1]) (headland), so that we should have been forced to make a detour in an easterly direction, if we were first to go to the shore to establish a depot, I resolved, after having consulted with Tobias, to try to sledge across the headland.

My secret thought — undoubtedly shared by Tobias — was that we should at once be able to procure some game. I was chiefly thinking of hares, as according to the statement of the Eskimo, who in 1900 accompanied Peary, there was no other game to be found in this place.

As soon as we reached land, we established a depot consisting of:

1) Provisions from sledge boxes and Knorr soups, in all for about ten days[2])
2) Two boxes of dog pemican, One box of greaves } Dog's feed for five days.
3) A good deal of personal property, skis, twelve quarts of petroleum, one quart of spirit.

We continued the journey with:

1) Provisions from sledge-boxes for about eight days[2]).
2) Six quarts of petroleum and a small jar of spirit, in all fuel for ten days.
3) Two boxes and a half of dog pemmican, One box of greaves } Dogs' feed for six days.
4) Tent, three sleeping bags.

The total weight, exclusive of sledges, about 400 lbs, or about 130 lbs to each sledge.

Travelling as light as that we ought, with fairly tolerable sledding, to have been able easily to make 60—70 km a day with fresh dogs; but with our worn-out and half-starved dogs we could hardly reckon on making more than half the distance, and consequently our prospects were by no means very rosy. If we got no game, we

[1]) The name is not retained but was replaced by Herlufsholms Strand (*H.* shore) and Kap Eiler Rasmussen.

[2]) A comparison with the list of provisions of May 1st (p. 315) shows that we had put ourselves on half rations, a necessary but rather dangerous measure when setting out on a long and fatiguing journey like the one before us.

could hardly count on getting further than Wykoff Island — PEARY's last station — and even then we should after that have to be content with a cursory reconnoitring at great distances of the coast of Peary Land from 82°30′ and to the interior of Independence Sound.

The journey across land had an enlivening effect, not only on us but also on our dogs. It is true that the bare spots of gravel, which we now and then had to cross, wore out the sledge runners and also the strength of the dogs, but on the other hand we were cheered up during our small geological, botanical and zoological investigations. The soil was shingle, nearest the beach as fine as clay, higher up somewhat coarser. The stones were granite, grey, brown, red, very rounded. A white shell was found on the beach up to 10 m above the level of the sea. The shingle continued all over the headland, the greatest height of which above the level of the sea may be as of Point 17 (about 65 m in the place where the determination of latitude was taken). Only quite close to the mountains did its character change, in that it became coarser, contained a good deal of erratic blocks (granite) and began to be covered with a thin layer of soil.

The vegetation was very sparse at the shore, though much more prolific than I had seen it anywhere on the sledge trip. On the highest part of the headland itself it became perhaps rather more sparse, but close to the mountains, where the layer of soil began, it became, under the circumstances, luxuriant (cyperaceæ, saxifraga), and already at this early period it apparently began to penetrate through the snow.

After having driven about ten kilometres on land, we saw the

Determination of latitude 7/V 09; $b = 761.0$; $t = \div 12$; ☊; hodometer distance from Station II 11.1 km ÷ 2 %. Direction a couple of degrees north of Pt. 16. Approximate altitude of telescope 65 m (see barometer and thermometer reading).

Telescope left						Telescope right					
Watch *K*	Vertical circle Vernier		Level		Horizontal circle	Watch *K*	Vertical circle Vernier		Level		Horizontal circle
	A	B	Obs.	Obj.			A	B	Obs.	Obj.	
11h43m15s	293°45′.8	46′.2	12.3	7.0	113°28′	11h44m59s	66°15′.6	15′.9	2.8	8.0	113°58′
46 26	46.1	46.5	12.0	6.9	114 18	48 04	15.6	15.9	2.6	8.0	114 46
49 50	46.1	46.4	12.0	6.8	115 11	51 10	15.9	16.2	2.6	8.0	
52 31	46.1	46.4	12.0	6.8	115 53	54 03	15.8	16.0	2.0	7.8	116 20
55 44	46.1	46.4	12.0	7.0	116 45	57 05	15.9	16.1	2.3	7.7	117 08
58 59	46.0	46.3	12.0	6.8	117 35	12 02 23	16.2	16.3	2.8	8.0	118 31

Point in the terrain	Vertical circle A	Vertical circle B	Level Obs.	Level Obj.	Horizontal circle	Azimuth
	Meridian point c. 116°					
18					39°38′	S 76 E
11/I					192 11	S 76 W
12/I					209 47	N 87 W
Telesc. left 14/I	272°16′.3	16′.6	8.2	3.0	248 31	N 48 W Compass 1.5
Telesc. right	87 45.2	46.7	2.0	6.8		
Telesc. left 17/I	270 25.9	26.0	12.0	6.8	70 10	S 46 E Compass 182.9
Telesc. right	89 35.5	36.0	6.0	11.0		

$$\begin{array}{r} 426°15'.9 \\ 293\ 46.3 \\ \hline 132°29'.6 \end{array} \qquad \left.\begin{array}{rl} z = & 66°14'.8 \\ \rho = & \div\ 15.9 \\ r = & +\ 2.1 \\ \delta = & +16\ 35.0 \end{array}\right\} \quad \varphi = 82°36'.0.$$

cranium and skeleton of a musk ox. Our spirits rose, the chances of fair hunting increased, but the cranium was possibly several years old, and we found no traces of excrements (excrements of hares we found immediately on the shore). Shortly afterwards we came across urinous formations frozen into the snow and due to a big beast; it might have been a musk ox, but it was not certain. But after that we had not driven many minutes, before we found the excrements, which now became more and more frequent, according as we approached the mountains. Then Tobias stopped short, turned round and said: "Koch, two musk oxen!" We took out the binocle and soon made sure that his eyes had not deceived him; the oxen were walking about at a distance of some four kilometres, grazing peacefully. Tobias — the born hunter and sealer — then arranged the hunt. He and I took three dogs each from our teams, and with them we started in the direction of the musk oxen, whereas Bertelsen remained with the sledges. It was very hard work to reach the oxen; the dogs were so tired that they lay down every few minutes, so that we actually had to drag them along; of course they could not understand, why Tobias and I could not take a walk without them. Even when we were at a distance of 30 m from the oxen, the dogs kept behind us. Then we let them loose and began to shoot at the oxen — it turned out that there were four oxen and two calves — but now the dogs became alive; they rushed forward and attacked the oxen from all sides, so that they had to stand still and defend themselves against the dogs, and thus they became an easy prey to our bullets. It was the usual practice of the musk oxen which was here followed: they formed a sort of square with the calves in the centre, and now and then made a sally against

Fig. 44. Coastal mountains at Herlufsholms Strand.
Drawn by Bertelsen from one of his paintings.

the keenest dogs, which practice is undoubtedly excellent when fighting wolf and bear, but which is of no use against a hunter provided with a rifle.

When the four cows had been shot, the dogs immediately pounced upon one of the calves, tore it to pieces and devoured it on the spot. On seeing this I raised my rifle in order to shoot the other calf at once, but at the same moment it came running towards me, quite happy and content; I could not murder it in cold blood, and again lowered my rifle. We then took out the entrails of the four animals and returned to the sledges followed by the calf. Our dogs, on the other hand, we had to leave behind; they threw themselves over the entrails of the cows and would not be driven away. The calf walked between TOBIAS and myself all the way back to the sledges, to the great amusement and surprise of BERTELSEN, and there it was photographed and — killed. We now drove with the sledges towards the animals we had shot, and succeeded in approaching them at a distance of one kilometre[1]). We immediately slipped the dogs and drove them towards the dead oxen, and then there was a feast of a peculiar kind. The dogs tore and slashed at the carcases, and all the while we three men were busy cutting out big chunks of meat and flinging them to our dogs. Gradually they began to be satisfied; they ate no longer of the meat, but tore off a bit of tallow here, a few hairs there, and evidently only continued eating, because they could not find it in their hearts to stop. A few of them were, however, already prostrate on the battle field; they lay on their sides, with their four legs stretched out, surfeited and gasping. Their bellies were round and protruding, but, on the other hand, their extreme emaciation was terribly evident, now that their skins were distended, and in spite of their thick coats the sharp spine and hip bones were a ghastly sight. But this made us all the happier that we could now feed them well for six to eight days, perhaps even longer; now our dogs should be permitted to rest for a couple of days, and being fed amply and well they would undoubtedly regain their strength.

When the dogs could eat no more, we cut out a large chunk of meat for ourselves, went back to our tent, pitched it and ate an excellent musk ox soup. We were now very tired. We had been on the go for twenty-six hours at a stretch, had travelled, that is walked, about 40 kilometres, and taken observations at three stations. We were badly in need of a rest in our sleeping bags; but first there was one more task to be performed: the oxen had to be cut up,

[1]) It was the lack of sufficient snow which prevented us from driving right up to the carcases.

8/V as they would otherwise be frozen stiff by next morning. So we went ahead with this not very agreeable work, tired but in very high spirits, and finally at 1 a. m. on the 8/V we could take to our sleeping bags, with a clear conscience and every reason to hope that we might attain our aim. We had then worked hard for thirty hours at a stretch, at a period when we were physically rather weakened by overwork, seeing that seventeen days of travel had elapsed since our last day of rest.

We slept for fourteen hours, and thus inaugurated our day of rest in a worthy manner. After that we fried a steak; as we had no butter, we used ox tallow, and it tasted excellent. But when we had eaten, peace was at an end, for no sooner had Tobias left the tent than he returned, thrust his head into it and said: "Koch, many musk oxen!" This time we set out, all the three of us, and with the majority of our dogs. A few kilometres from us a herd of musk oxen were grazing, consisting of two bulls, three cows, a two year-old bull calf, two one or two year-old cow calves, and three sucking calves, 88, 85 and 87 cm long, in all eleven animals. When the dogs attacked them, they formed a square, after which Tobias and Bertelsen began to shoot, while I photographed them.

We now returned in order to fetch harness and traces for the dogs, with the view of making them drag the oxen to the tent — sledges we could not use — but before we got back, a heavy drift of snow set in, so that it seemed uncertain whether we could find the tent, in case our traces had been effaced. We immediately returned to the tent, but in order to do something, now that we had set about it, we fetched the meat from the day before and stowed it in our tent. It would never have done to leave it in the open, as the dogs would then have been in a state of perpetual surfeit and consequently unfit for work, when in a day or two we were again going to start.

It was indeed a grand day for us, as we had thought it would be, when in the morning we had hoisted our small silk flag. We had now presumably dogs' feed and provisions for fifteen to twenty days, and thus we might, without fear of losing our time and failing in what we had set out to do, put up with the snowstorm which now followed. Bertelsen's becoming snow blind in his left eye caused me, however, a good deal of anxiety, but I hoped it would not prevent him making some of his characteristic sketches from this Ultima Thule.

From midnight 6—7/V to noon 7/V nearly calm, in the beginning clear, calm air with a cover of clouds 3, stratus; later towards 8 a. m. rather hazy and dim. After noon the haze became thicker, and the

weather began to be overcast. At about 5 p. m. 7/V the weather suddenly became quite overcast, and there was a light fall of snow. Very faint wind from NW. Shortly afterwards the snowfall ceased, and the clouds lifted; but towards 7 o'clock it was again overcast, so that we could barely distinguish the sun's position in the sky. At midnight 7—8/V we had 5 m wind from NW with a faint drift, but no fall of snow. From 1 a. m. till 5.30 p. m. on 8/V the sky remained overcast, and the wind blew with a velocity of 5 m, not evenly but in squalls. At 5 p. m. it came on to snow. Temperature $\div 10°$. The wind still came in gusts from NW, but gradually it became fresher.

Clock comparison 8/V p. m. Chron. 57203 $20^h04^m00^s$, $20^h04^m30^s$
Watch *K* 5 58 46.6, 5 59 16.6

At midnight 8—9/V the velocity of the wind was rather constant, about 10 m, all the time with snowfall and heavy drifts of snow. At 4.30 a. m. 9/V the temperature $\div 9°$. At 5 a. m. the weather unchanged. God, how we sleep! At 10 a. m. The snow storm increased. The velocity of the wind perhaps 15 m; heavy drift of snow, but perhaps no snow fall. 8 p. m. The snow storm continues. It is practically impossible to leave the tent. However, it seems to me as if the velocity of the wind has decreased somewhat during the last few hours. 10 p. m. The storm continues, but seems steadily decreasing.

4 a. m. The storm continues. Now we are quite tired of lying in our sleeping bags. We spend the time learning the Eskimo language and roasting calf's meat in ox tallow. BERTELSEN's snow blindness does not seem very serious. I have twice treated the affected eye with cocaïne; he declares he is better after his two day's rest in the tent.

10 a. m. The snow was still drifting, about 5 m wind from NW; however, the weather was so much clearer that we could fetch the eight musk oxen which lay in the talus. We had been surprised by the snowstorm, so we had not had time to remove the entrails, and the meat was spoiled, as far as we were concerned, but still excellent food for the dogs. We now transported the oxen to the tent — about 2 km — in two échelons, as we put our dogs to them and dragged them to the tent. After that came the slow and dull flaying and quartering of the carcases, which was not finished until midnight. It seems as if we only got food here for our dogs for about fifteen days. The snow storm has caused a little accident, in that the tripod of my theodolite has become buried in it. BERTELSEN

and I have dug for it alternately for several hours, but without success; I must try to get along without it[1]).

The weather slowly improved. However at 7 p. m. we had still 5 m wind, but the sky began to be clear — cover of clouds 9 — NNW; just before midnight the sun appeared, and so I got a latitude.

11/V We have now eaten nothing but meat of musk oxen for four days. Bertelsen is, I think, already tired of it, and I won't deny that a good plate of pea soup at the present moment seems to me a particularly desirable thing.

Peary Land. Station IV.

Determination of latitude 10—11/V; midnight; ☋; $b = 765.0$; $t = \div 12.0$. On land. The camping site where the musk oxen were shot. Depot.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
11h39m10s	280°31′.3	31′.7	9.9	4.2	11h41m25s	79°29′.7	30′.1	5.8	11.3
44 00	31.3	31.8	10.2	4.7	46 25	29.8	30.2	5.0	10.5
48 25	31.2	31.6	10.2	4.6	50 40	29.8	30.2	5.5	11.1
53 05	31.2	31.5	10.0	4.2	55 30	29.9	30.2	5.5	11.3
58 40	31.4	31.7	9.8	4.1	60 50	29.8	30.1	5.5	11.3

439°30′.05
280 31.35
158 58.7
$z = 79°29'.4$
$\rho = + 15.9$
$r = + 4.8$
$\delta = + 17\ 32.1$
97°22′.2
$\varphi = 82°37'.8$

Determination of time 11/V; forenoon; ☌; $b = 764.0$; $t = \div 11.8$. Same place as the determination of latitude 10—11/V.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
6h50m18s	289°09′.9	10′.3	9.0	3.5	6h53m56s	70°45′.2	45′.6	5.0	10.7
57 20	23.9	23.5	11.0	5.6	7 04 35	24.5	24.7	6.8	12.1
7 06 42	40.2	40.6	12.5	7.0	11 32	11.9	12.2	7.0	12.3
14 08.5	53.8	54.2	12.0	6.8	20 25	69 55.3	55.7	6.0	11.0

[1]) Before the expedition left Denmark, I had foreseen this possibility that a tripod might become lost on a sledge journey. The boxes containing the theodolites were consequently fitted up in such a manner that the instrument, in cases of emergency, could be placed upon them. Even if the box were filled with stones, the weight of the instrument and the box would, however, be too small to ensure a fairly safe adjustment. Therefore the box had to be placed with special care, for instance, by being wedged into a crust of snow and cemented with same. While handling it, I had further to take special care not to get the instrument out of verification. With the constant shifting from teleseope right to telescope left, the manipulation and reading off gave me a good deal of trouble, as I was obliged to lie on my stomach during the observation, and to prevent my clothes getting filled with snow, I had to put on a wind-proof anorak and wind-proof trousers. The inconvenient and difficult conditions here left their distinct mark on the following observations.

Fig. 45. Coastal mountains at Kap Henry Parish.
Drawn by Bertelsen from one of his paintings.

The level very unsettled on account of radiation. We constantly had to adjust the levelling screws. Mist everywhere on the horizon. Terrestrial measuring impossible.

Clock comparison 11/V, forenoon, Chron. 57203 $9^h52^m00^s$ $9^h52^m30^s$
Watch *K* 7 36 25.4 7 36 55.6

Started at 11.45 a. m. in bright sunshine, but very heavy sledding after the snowstorm. We left a depot consisting of:

$2^1/_2$ boxes of dog pemmican, 1 box of greaves, meat of musk oxen for 25 dogs for about 13 days.

We intended to move down to the sea ice, but we only left the shore after a journey of 18 km, because it lay nearly one degree further east than supposed. According as we approached the coast, the country became flatter and more and more covered with snow, so that we could drive for a kilometre without coming upon bare spots. The gravel in these spots became finer and finer and was at last replaced by a mixture of clay and pebbles, which bore a striking resemblance to bottom moraines. This mixture in one place came very near to being a conglomerate. The pebbles in it, which were not rounded in any considerable degree (in the samples there just happens to be one very rounded stone) were sorted and situated in layers in the clay. The conglomerate contained shells; it was found about 10 m above the level of the sea and only about 2 km from the coastline.

The transition to the sea ice was only discernible on account of a somewhat disintegrated pressure ridge which marked the high water of the spring tide. After having passed this ridge we kept on driving on land for another half kilometre, before we reached the sea ice[1]). In this place the ice bears no visible traces of the daily tide.

By and by a very thick mist had set in. As it was impossible in these conditions to follow the faintly marked coast line, and as the snow on the sea ice seemed firm and even, I let Tobias set a course due north. By this course we got at last into the packs of palæocrystic ice. At this period — 7.30 p. m. — we had made about 30 km, which was quite sufficient for our surfeited dogs. Consequently we camped on the pack ice.

The weather: At noon bright sunshine, though with fog banks on the horizon; a burning sun, calm. At 3 p. m. the fog began to

[1]) For a long time we did not know whether we were on land or on sea, and once we tried to dig through the layer of snow, in order to see whether there was land or ice under us. We gave up the attempt after having dug a hole of 2 m without reaching the ground.

set in. At 4.30 p. m. everything was hidden by the fog; the wind was shifting and very faint.

How worn out we were by the journey to Peary Land appears most clearly from the fact, that after a three days' snowstorm, when we had spent most of our time in the sleeping bags, we were extremely sleepy and indolent, so that only by exerting all our energy were we able to fetch the musk oxen and skin and quarter them. Our indolence now happily seems gone. The easy day's march of 30 km has done us good. Bertelsen seems cured of his snow blindness — he has been let off easily.

12/V The weather still unchanged. All through the night we have had fog and calm, and this still holds good now at 8.30 a. m.

We have had nothing to eat but the meat of musk oxen for four days. I am sick of it, and so is Bertelsen. The stench of the half-rotten meat, which takes up one fourth of our tent, perhaps contributes towards disgusting us with it. The dogs smell abominably.

Started at 10.45 a. m. The fog partly lifted at 12 (noon). Latitude at noon 82°51′. The course had been west, distance made 4.7 km. Continued in a westerly direction towards land at 1.30 p. m., with a course of ½ point (5 degrees) to the north of the direction at Point 21[1]). With this course we reached the coast 14.8 km ÷ 2 % from our noon position. We reached the coast at the northern part of an ingoing small curve, from which the coast extended in S 65 E—N 25 W. Point 21 is found in direction S 60 W. The mountain range on which Point 21 is situated stretches inland in a direction N 80 W. The breadth of the foreland is 1 to 2 kilometres. At 6.15 p. m. hodometer distance since we reached the coast 7 km ÷ 2 %. The direction has not been N 25 W; this was only in the beginning. The main direction of the last 7 kilometres is N 40 W. From Point 21 or a few kilometres more to the north the coast seems to form a large bay, which again appears to extend in a northern direction, as far as the northern part of Wyckoff Land. The depth of the bay is hardly more than 4 km. The southern part of this bay has a little fjord, with a direction N by E—S by W; it is only about 2½ km broad at the mouth and about 10 km long. It seems to run in west of Point 21[2]).

[1]) Kap Clarence Wyckoff.

[2]) These obscure, mutually contradictory remarks were written down during the sledge journey, point by point, according as I could form an idea of what I saw. Now, I suppose, it is only possible to understand them when, with the sketch-map before one, one imagines oneself following our route past Kap Clarence Wyckoff; on the other hand I had, of course, no difficulty in under-

Fig. 3. Looking S.E. and E. from May 14th, 1907, afternoon.
Henry Land seen from Station K.37. 4 miles. 5 Rock at Kap Clarence Wykehill (see Pl. VI.)
16 Kap Henry Forsyth. 21 Kap Clarence Wykehill. 24, 25 & 31 Scoresby Land.
27, 28, 32 & 33 Hold Land. 29 Daly Mountains Peak 1900.

Fig. 4. Looking S.E. sketch from Petrel's Camp, May 13th 1907.
Henry Land seen from Station P.35 (see Pl. VI.)
16 Kap Henry Forsyth. 21 Kap Clarence Wykehill. 24, 25 & 31 Scoresby Land.
29 Daly Mountains Peak 1900.

Fig. 5. Looking S.E. sketch from Camp I. of May 13th 1907.
Henry Land seen from Station K.35, Kap John Playfair (see Pl. VI.)
35 Stenenaegdommen. 36 Handercastellet. 37 & 38 Peninsula of Dr. E. Hyde Land.
2 Mgr. Schmidtsnæse. 29 Daly Mountains Peak 1900. 39 Daly Mountains 1150.
41 Kap Hodgkinson.

Peary Land. Station V.

Determination of latitude 12/V, ☌, $b = 772.6$, $t = \div 13.0$.

On the ice 4.7 km west of camping site 11—12 V.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
11h53m59s	294°51′.3	51′.7	12.0	6.3	11h56m10s	65°09′.9	10′.4	2.5	8.0
58 05	51.2	51.5	11.2	5.8	59 49	10.0	10.4	3.8	9.6
12 01 33	50.0	51.3	11.5	5.8	12 02 58	10.1	10.6	5.0	9.7

425°10′.0
294 51.5
130°18′.5

$z =$ 65°09′.3
$\rho = \div$ 15.8
$r = +$ 2.1
$\delta = +17$ 55.5
$\varphi =$ 82°51′.1 [1])

Chron. 57203 15h38m00s 15h38m30s
Watch K 1 17 32.4 1 18 02.6

Determination of azimuth 12/V, afternoon, ☉, $b = 772.6$, $t = \div 13.0$.
(Bertelsen's sketch: position at noon, Sunday, May 12th, 1907 [2]).

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telescope left 1h04m08s	295°01′.1	01′.7	11.5	6.0	309°51′	70°.9	S 17 W
Telescope right .. 06 04	65 00.9	01.5	4.0	9.5	310 24	71.9	Variation 54°
Point in the terrain:							
12/I					285 08		S 8 E
14/I					295 28		S 2 W
16/I					308 32		S 15 W
19/I					347 59		S 48 W
20. Main direction of valley					362 44		S 69 W
21. K. Clarence Wyckoff ...	273°00′.6	01′.6	16.0	7.5	21 55	143.2	S 89 W
	87 00.1	00 7	4.0	10.0			
22. Tangent to land					51 41		S 119 W
23. Peak towards north [1]) ..					60 37		S 128 W

[1]) Daly Mountains.

Last night we stopped at the pack ice. From camping site 11—12/V in a southern direction the pack ice is not seen on a stretch of about 30 km; but one may perhaps take it for granted that its edge here extends parallel with the coast at a distance of about 15 km, as the ground in this place must have but a slight gradient. The pack ice on which we stopped last night was heavy palæocrystic ice, very

standing them, when during the sledge journey on Peary Land I made my sketch map. This shows that it may be expedient to draw one's map at the spot itself.

[1]) The final computation after our return gave $\varphi = 82°52'.1$.

[2]) See Fig. 43.

much disintegrated. From camping site 11—12/V and in a northern direction the edge of the pack ice comes nearer to the coast; at 82°55′ the distance is about 3 km. The pack ice in this place is more rugged and looks fresher. This harmonizes with the fact that the foreland is here not nearly so flat and is narrower, as well as with the fact that here again one can distinguish the tidal pressure ridges.

Peary Land. Station VI.

Determination of time 12/V, afternoon, ☉, $b = 773.3$, $t = \div 14.5$. On the ice, 1 km from the coast. As regards the position see diary. (Bertelsen's sketches of May 12th, afternoon[1])).

Telescope left					Telescope right				
Clock time	Vernier A	Vernier B	Level Obs.	Level Obj.	Clock time	Vernier A	Vernier B	Level Obs.	Level Obj.
7h06m00s	286°05′.6	05′.9	12.0	4.8	7h07m17s.5	73°57′.6	58′.4	3.0	10.0
08 40	00.7	01.1	11.0	3.8	09 36.5	74 01.4	02.1	4 5	11.5
10 51	285 57.3	57.7	11.5	4.5	11 57	05.7	06.2	3.5	10.5

Chron. 57203 $22^h59^m00^s$ $22^h59^m30^s$
Watch K 7 37 29.5 7 37 59.7

Determination of azimuth 12/V, afternoon, ⊕, $b = 773.3$, $t = \div 14.5$.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Azimuth
Telescope left 7h13m52s	285°52′.0	52′.5	11.5	4.5	9°36′	N 79 W
Telescope right 15 22.5	74 11.6	12.4	2.0	9.3	10 02	
Point in the terrain:						
16/I K. Henry Parish					224°02′	S 35 E
21/V K. Clarence Wyckoff	277 28.3	28.6	12.5	5.5	264 17	S 15 W
	82 32.7	33.1	5.5	12.6		
24. Mountain in centre of valley[1])					353 41	N 85 W
25. Peak north of valley[1])					3 16	N 76 W
23/V					30 00	N 49 W
26. Tangent towards north					34 11	N 45 W
22/V					31 44	N 48 W

[1]) The valley turned out to be G. B. Schley Fjord.

[1]) See Fig. 46.

Fig. 49. Kap Clarence Wyckoff. In the foreground Peary's Cairn.
Drawn by Bertelsen from one of his paintings.

10 p. m. At hodometer reading 37½ km ÷ 2 % we came across Peary's Cairn. Took out the report and deposited the following:

"A sledge party of the Mylius-Erichsen's Danmark-Ekspedition — "Lieutenant Koch, artist Bertelsen and the Eskimo Tobias Gabriel-"sen — arrived here May 12th 1907, 10 p. m., on journey northward. "I have taken R. E. Peary's report which was deposited here in this "cairn.

I. P. Koch."

This was a surprise, as we had not expected to find the cairn in so southerly a place — 82°58′.4, but at the same time it was a solemn moment. We had now got so far as we were to go according to our instructions, and yet it looked as if we might get a few days' march further and finish Peary's observations. Solemn also it was to come across the traces of the famous American explorer and to hold his autograph in our hands. The flag was brought out and fastened to the cairn, in order to express our mood. The cairn and flag were photographed. Bertelsen made two sketches.

Peary Land. Station VII. Peary's Cairn.

Determination of latitude 12—13/V, midnight, ☋, $b = 772.3$, $t = \div 17.0$.

Peary's Cairn. Hodometer distance from camping site 11—12/V 37.5 km ÷ 2 %.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
11h33m45s	281°23′.0	23′.5	13.6	6.0	11h55m45s	78°37′.7	38′.5	1.5	9.0
58 50	22.7	23.2	13.0	5.5	60 15	37.9	38.6	3.0	10.7
62 05	22.7	23.3	13.5	6.0	64 00	37.7	38.6	3.0	11.0

438°38′.3
281 23.0
157°15′.3

$z =$ 68°37′.7
$\rho =+$ 15.8
$r =+$ 04.8
$\delta =+18$ 03.3
97°01′.6
$\varphi =$ 82°58′.4

Determination of time 13/V, afternoon, ☋, $b = 774$, $t = \div 12.0$. 13/V

Peary's Cairn.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
5h39m49s	289°00′.0	00′.5	12.0	5.0	5h41m00s	71°03′.6	04′.2	3.5	10.3
42 38.5	288 54.3	55.0	11.0	3.8	43 34	08.3	08.6	5.0	12.4
44 45	50.4	51.0	9.5	2.4	45 56	12.8	13.1	4.0	11.0

Chron. 57203	20h38m00s	20h38m30s
Watch K	6 17 44.8	6 13 14.4

Determination of azimuth 13/V, afternoon, ⊕, $b = 774$, $t = \div 12.0$.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telescope left 5h47m0s9	283°46'.2	46'.8	9.5	2.5	244°51'	145.1	
Telescope right 48 49	71 17.8	18.5	4.0	11.2	245 17	144.7	S 89 W
Point in the terrain:	(Bertelsen's sketches from Peary's Cairn[1])						
16/I K. Henry Parish					113 53		S 42 E
21/V K. Clarence Wyckoff	273 42.6	43.2	9.3	2.0	124 09	235	S 32 E
	86 18.4	18.9	4.6	12.0			
27. Interior of fjord (not the direction of the fjord)					152 39		S 14 E
28. Entrance to valley					176 14		S 10 W
24/VI Mountain	271 42.6	42.5	10.0	2.8	230 38		S 74 W
	83 19.1	19.4	5.4	12.6			
25/VI Mountain	271 54.3	54.6	9.5	2.0	252 05		S 96 W
	88 06.6	07.0	3.8	11.0			
29. Mountain	272 08.2	08.8	11.0	3.8	269 42		S 113 W
	87 52.4	52.9	4.0	11.2			
30. Coast, west side of Schley Fjord					269 42		S 113 W
23/V Peak					287 26		S 131 W
26/VI (Only approximate, pack ice hindering)					292 51		S 137 W

[1]) See Fig. 47.

Started at 6.30 p. m. Course towards Point 30.

2 km: course right between Point 23 and Point 30. The coastline continues towards Point 30.

3 km: The coastline deflects towards WSW Bank with shells.

8½ km: The coast of G. B. Schley Fjord has the direction SW. Point 25 seems to be nearly off the middle of the fjord. In its interior the fjord falls a little towards south??

9.45 p. m. Distance 20.3 km ÷ 3 %. From 10 km to 20.3 km the course has been towards Point 23. At this period Point 29 is in the West, Point 30 in the WSW, Point 25 in SW½W. The coast off Point 25 in SW by S, Point 24 in S¼W. The distance from the west coast of Schley Fjord is now 1 to 2 km. The pack ice approaches the land within half a kilometre on the south side of the entrance to Schley Fjord. On the north side it seems to be 2 to 3 km off land.

Continued the same course towards land: reached it on 22.2 km ÷ 3 %.

14/V 11.30 p. m. 29½ km ÷ 3 %. Point 29 in WSW 38.2 km ÷ 3½ %. Most easterly point of Skagen[1]). Point 21 in SE by S, Point 23 in NW by W. From here course NNW to 45.4 km ÷ 3 %, where we

[1]) This point Peary had called Kap John Flagler.

reached the northern point of Skagen. Course west. Stopped at 3.15 a. m. Hodometer distance 49.6 km ÷ 3 %.

Determination of time 14/V, forenoon, ☌, $b = 773.0$, $t = \div 10.0$. Station VIII on the ice at the mouth of Hyde Fjord, ½ km from the land towards the south.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
6h23m02s	288°32′.3	32′.6	12.2	7.5	6h24m23s	71°26′.7	27′.0	2.2	7.0
25 40	36.7	37.2	11.7	6.9	27 04	21.8	22.4	2.0	6.9
28 11	41.1	41.7	11.3	6.7	29 42	17.6	18.1	2.0	6.9

Velocity of the wind 1—4 m (it came in gusts) from SE; cover of clouds 3, cirro-stratus in streaks SE—NW.

Determination of azimuth 14/V, forenoon, ⊕, $b = 773.0$, $t = \div 10.0$. Same position as that of the determination of time.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telescope left 6h31m44s	288°47′.5	48′.0	12.0	7.0	357°00′	327°.1	
Telescope right 33 22	71 10.8	11.2	3.0	7.6	357 27	328.1	S 84 E
Point in the terrain:	(Bertelsen's sketches from 14/V—Skagen[1])						
31. Tangent to Skagen.....					15°40′		S 66 E
32. Mountain (29?)	273°07′.6	08′.1	7.0	2.3	90 00		S 9 W
	86 53.9	54.1	7.7	12.4			
33. Mountain[2])	272 30.0	30.4	6.5	1.6	124 39	95.4	S 43 W
	87 30.8	31.2	8.4	13.0			
34. Dark slope[3])					146 13		S 65 W
35. Coast.....					157 21		S 76 W
36. Coast.....					166 03		S 85 W
37. Mountain, snow capped[4]) .	271 46.2	46.6	7.1	2.3	188 45		S 107 W
	88 13.8	14.5	5.9	10.6			
23/V. Mountain	271 54.2	54.7	7.3	2.5	201 38		S 120 W
	88 10.7	11.6	4.0	8.9			
38. Mountain	271 49.9	50 3	8.0	3.2	191 52		S 110 W
	88 09.6	10.0	4.8	9.5			
39. Mountain (Bridgman)	271 47.6	48.2	8.5	3.6	206 32		S 125 W
	88 13.3	14.1	3.8	8.5			
26/VI					210 11		S 129 W
40.					211 42		S 130 W
41. Tangent to foreland					227 05		S 146 W

[1]) See Fig. 48.
[2]) Dannebrogstinden (see the final map, Pl. IV).
[3]) Hundeskrænten (the dogs' slope).
[4]) Stjernebannertinden (Mount Stars-and-Stripes, see the final map, Pl. IV).

Chron. 57203 $8^h32^m00^s$ $8^h32^m30^s$
Watch *K* 6 04 48.2 6 05 18.2 (forenoon).

Determination of latitude 14/V, Ω, b = 772.0, t = ÷ 7.3.
Station VIII, Skagen, on the ice ½ km from land. Moment of culmination about 12^h06^m, l = about 25½ west of Grw.

Telescope left					Telescope right					425°04′.3
Watch *K*	Vernier		Level		Watch *K*	Vernier		Level		294 57.2
	A	B	Obs.	Obj.		A	B	Obs.	Obj.	130°07′.1
$12^h02^m37^s$	294°56′.9	57′.5	11.2	6.3	$12^h04^m28^s$	65°04′.1	04′.6	5.0	9.8	z = 65°03′.6
06 18	56.9	57.4	11.4	6.9	08 05	04.3	04.6	6.5	11.0	ρ = ÷ 15.8
10 01.5	56.8	57.4	11.4	6.9	11 32	04.4	04.7	6.5	11.0	r = + 2.0
13 46	56.6	57.3	11.1	6.7	15 32	04.6	04.9	7.0	11.3	δ = +18 25.8
										φ = 83°15′.6

The weather 12—13/V. From noon on the 12th the fog lifted, though the weather did not become quite clear; the banks of fog remained on the horizon and now and then set in, as for instance about midnight. The wind was northwesterly and very faint (about 1 m). In the course of the forenoon of the 13th the wind shifted to SE, still extremely faint. On the 13th the weather was hazy, but the banks of fog had disappeared. The weather remained unchanged during the whole of the 13th. At 3 a. m. on the 14th strong gusts began to set in from SE, but not until 8 a. m. had the velocity of the wind become steadier, about 5 m. Cover of clouds 3, cirro-stratus. At 12 noon on the 14th wind SE, velocity 8 m, cover of clouds 2, cirro-stratus with direction SE—NW, light drift, no fall of snow. 8 p. m. 14/V. From 4 p. m. to 8 p. m. the wind has fallen light; it is now easterly, with light gusts; velocity of the wind 1 to 2 m. Cover of clouds 1 — western and northern horizon — cumulus and cumulo-stratus (perhaps banks of fog towards north).

14/V Started at 9.50 p. m. Our intention to enter Hyde Fjord altered, as it was filled with fog. Instead we now kept towards K. Bridgman.

10 p. m. Faint wind — 1 m — from NNW. The fog sets in across the country. Course NW. Got across Hyde Fjord after 18.4 km. The coastline here declines N. by E.

At 10.31 p. m. a very faint fall of snow began. As long as the sun was shining through the fog, the air seemed filled with small, bright ice needles; as the sun was altogether obscured by the fog, the ice needles proved to be quite fine particles of snow. Before 11 p. m. the velocity of the wind had become 5 m. The fall of
15/V snow and the velocity of the wind held out till about 3 a. m. The snow stopped, the wind fell light, and at 6 a. m. it had a velocity

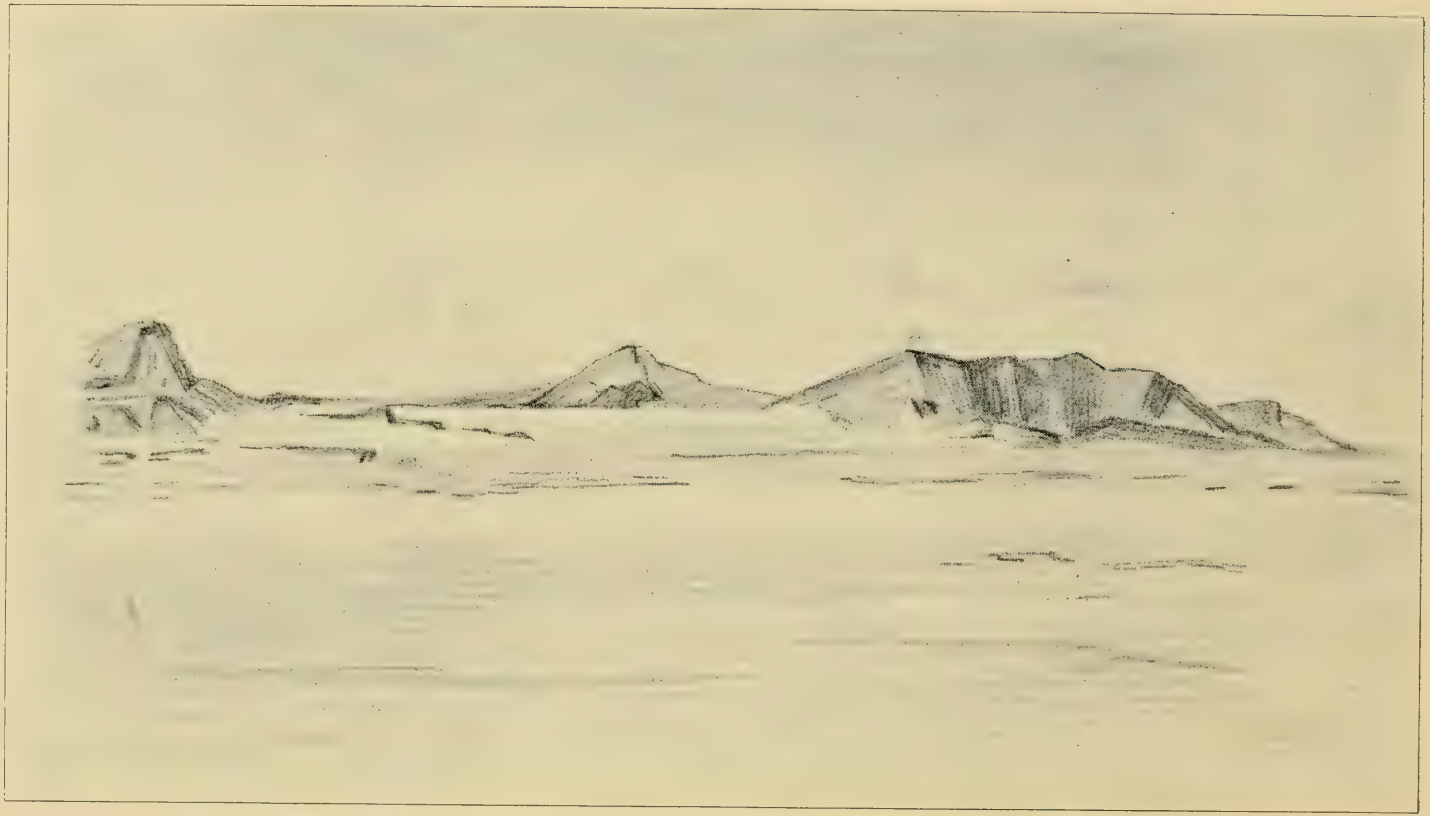


Fig. 50. View of the land between Fr. E. Hyde Fjord and Kap Bridgman seen from Kap John Flagler.
Drawn by Bertelsen from one of his paintings.

of nearly 1 m. At 6 a. m. the temperature ÷ 14°. Stopped at 6 a. m. Hodometer distance 43¼ km. I suppose that we are at Kap Bridgman, but nothing is visible on account of the fog.

Peary Land. Station IX.

Chron. 57203	$20^h41^m00^s$	$20^h41^m30^s$
Watch *K*	6 07 46.0	6 08 16.0 (afternoon)

Determination of time 15/V, afternoon, ☉, $b = 769.3$, $t = \div 10.5$. On the ice in the immediate vicinity of the coast, off Kap Bridgman.

Telescope left					Telescope right				
Watch *K*	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch *K*	Vernier A	Vernier B	Level Obs.	Level Obj.
$6^h22^m13^s.5$	288°39′.7	40′.4	11.6	5.9	$6^h23^m28^s$	71°23′.1	23′.5	5.0	11.0
24 49	35.2	35.9	11.6	5.9	25 49.5	27.2	27.7	5.0	11.0
27 15.5	31.2	31.7	12.0	6.2	28 20	31.2	31.7	5.0	11.0

Determination of azimuth 15/V, afternoon, ☉, $b = 769.3$, $t = \div 10.5$.

Watch *K*	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obs.	Horizontal circle	Compass	Azimuth
Telesc. left .... $6^h32^m22^s$	288°22′.4	23′.1	11.8	6.0	346°02′	153°.7	
Telesc. right .. 34 31.5	71 41.8	42.4	5.0	11.0	346 36	152.7	S 95 W
Point in the terrain:							
39.	276°03′.8	04′.4	12.0	6.0	294°37′	102°.0	S 43 W
	83 57.3	57.6	2.5	8.2			
42. (perhaps 38/VIII).....	Pointed with diopter; pointing with telescope impossible on account of snow drift				311 41		S 60 W
43. (perhaps 23).....					320 28		S 69 W

(The observation interrupted on account of fog and snow drift).

Determination of latitude, midnight 15—16/V, ☉, $b = 769.2$, $t = \div 15.3$. Station IX, on the ice off Kap Bridgman.

Telescope left					Telescope right				
Watch *K*	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch *K*	Vernier A	Vernier B	Level Obs.	Level Obj.
$12^h07^m05^s$	282°38′.6	39′.3	12.7	6.0	$12^h09^m05^s$	77°22′.3	23′.0	2.0	8.5
13 10	38.6	39.2	13.5	6.8	16 25	22.5	23.2	2.5	9.0
19 30	38.6	39.2	13.0	6.2	21 35	22.5	22.9	2.0	8.6

	437°22′.8	16/V
	282 38.8	
	154°44′.0	
$z =$	77°22′.0	
$\rho =$	+ 15.8	
$r =$	+ 4.1	
$\delta =$	+ 18 47.6	
	96°29′.5	
$\varphi =$	83°30′.5 [1]	

[1]) cf. the full computation on pp. 267—268 which gives $\varphi = 83°29'17''$.

Determination of azimuth 16/V, forenoon, ⊕, $b = 769.2$, $t = \div 15.3$.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Azimuth
Telescope left ... $12^h28^m20^s$	282°08′.1	08′.8	13.0	7.0	165°39′	
Telescope right . 29 39	77 52.1	52.6	2.8	8.4	166 00	N 4 E
Point in the terrain:						
21. (not quite certain)					302°38′	N 141 E
32. Mountain					318 04	N 156 E
33.					333 22	N 173 E
39. Kap Bridgman					27 07	S 45 W
42. (perhaps 38)	274°59′.9	60′.3	13.5	6.5	44 33	S 62 W
	85 01.7	02.1	4.7	11.1		
43. (perhaps 23)	274 47.4	47.9	10.0	3.3	53 40	S 71 W
	85 13.8	14.1	4.0	10.5		
44.	273 32.0	32.3	9.8	3.0	61 05	S 78 W
16/V	86 29.5	29.7	4.8	11.0		

15/V 2 p. m. Calm. The sun begins to break through the clouds. 3 p. m. Faint wind SE. 5 p. m. Velocity of the wind 8 m, SE, snow drift. 6 p. m. Same as at 5 p. m. The banks of fog are still on the horizon; the mountains ashore are nearly covered with the snow drift. Temperature $\div 10.5$.

The coast east and north of Kap Bridgman flattens into the sea, in exactly the same manner as on the east side of Skagen and at Peary's Cairn, but not with such an imperceptible transition as off Henry Parish. The coastline is here rather sharply defined by means of an inconsiderable tidal pressure ridge. The beach is covered with pebbles, chiefly granite. Off the northern entrance to Fr. Hyde Fjord I found a few remains of plants in the ice. The stems were frozen into the ice, but they did not seem to have roots in the place itself, as the former lay out open on the ice. As there was a good deal of glare ice here, there must, I suppose, also now and then be open water in this place.

With a good deal of trouble I succeeded in getting a determination of time at 6 p. m., and I also hope to be able to get a midnight latitude. This will be our most northerly camping site, and we are making preparations to celebrate the occasion. The flag has been taken out, and we are going to have a grand banquet, consisting of musk ox soup, boiled musk ox, blood pudding and chocolate. I am looking forward to these culinary delights.

If the weather permits, and we can find the time to do so, we are going to drive 15 km in a westerly direction with empty sledges, chiefly in order that Bertelsen may make a sketch of James Hill

and Morris Jessup, and so that I may undertake a few measurements of the heights of mountain peaks.

10½. Calm, dim; the mountains inland are lying free; fog on the horizon. 11 p. m. faint wind NNW — 1 m — it seems as if the mist is setting in again. No clouds in the zenith.

Started at 2.30 a. m. Mist over land and also over the sea. 16/V
Cover of clouds 10; wind 3 m from WNW. Commenced the home journey, at the present bound for Hyde Fjord. Drove at once to the shore, built a cairn and deposited report (rough draft in drawing portfolio[1]).

8 a. m. 34 km: Hyde Fjord which from the point, where we touched the west side of the fjord yesterday[2]), has bent its western coastline in five small curves in a southern direction, now rather suddenly turns round a flat headland, after which the coastline goes in SW by S in a fresh bay. Here the mountains begin with a SW direction; a narrow foreland between the flat headlands.

36 km: Again a flat headland and, as it seems, a rather big curve, where the direction of the coastline is at first westerly.

44½ km: The just mentioned great curve, which falls into two parts, a big northeasterly and a small southwesterly, ends. The no longer quite flat headland now enters upon a new curve, terminating at 48 km. Stopped and pitched our tent.

The weather on 16/V. The wind kept blowing from WNW, 3—5 m velocity, and quite a light snowdrift, until 9 o'clock. At that period we had got into Hyde Fjord, where the weather was clear, with a few fog banks and nearly calm. From 10 a. m. quite a faint breeze from NE. The fog was still over the sea, and also over a considerable distance of the fjord.

10 p. m. calm, clear. Fog banks visible out to sea.

Noon latitude 83°14'.5. Determinations of time and bearings in the course of the evening. From 8 to 10 o'clock I took a little walk inland. Up to as much as 100 m above sea level and perhaps still higher, the surface is covered with pebbles (granite); the vegetation is very sparse. Only in one place, in a crevice, where during the summer there is a little running water, was there a suggestion of a continuous carpet of vegetation. The number of the species also seemed very small. Traces and excrements of musk oxen. The plants collected are all from an altitude of 70—100 m and from localities facing south. The stone sample is from an altitude of about 100 m; the mountains seemed everywhere to be of this species of stone; it is rather slaty and strongly intersected with veins of

[1]) Published in Medd. om Grønland XLI, p. 127.
[2]) 15/V nearly 1 a. m.

quartz. The stone sample is marked No. 1. In altitude (barometer) of 20 m shells were found, No. 2. Besides the collected plants we also saw a willow.

Station X. Determination of latitude 16/V, ☌, $b = 770.4$, $t = \div 12.5$. Fr. Hyde Fjord, north side.

Telescope left					Telescope right					
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	
12h08m50s	295°26′.9	27′.3	13.0	7.0	12h12m20s	64°34′.1	34′.6	3.0	9.0	$z =$ 64°33′.7
15 15	26.9	27.3	12.0	6.0	17 00	34.0	34.8	4.0	10.0	$\rho = \div$ 15.8
19 55	26.9	27.3	12.0	6.0	21 40	34.3	34.8	3.7	9.7	$r = +$ 2.0
										$\delta = +$ 18 54.6
										$\varphi =$ 83°14′.5

424°34′.4
295 27.1
129 07.3

Chron. 57203 $21^h31^m00^s$ $21^h31^m30^s$
Watch K 6 53 40.5 6 54 10.5

Station X. Determination of azimuth 16/V, afternoon, ⊕, $b = 764.2$, $t = \div 12.0$. Altitude of telescope 50 m.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telescope left 7h06m40s	287°37′.5	38′.0	12.5	6.5	6°53′	163°.9	
Telescope right .. 08 16	72 26.1	26.7	6.0	12.0	7 20	162.5	S 106 W
Point in the terrain:	(Bertelsen's sketches of 16/V[1]), Station X)						
45. Tangent to Skagen.....					166°30′		N 85 E
32. Peak	272°09′.0[2])	09′.5[2])	12.2	6.2	204 24		N 123 E
	87 06.2[2])	06.6[2])	3.0	9.0			
33. Peak	273 05.1	05.4	12.0	5.0	227 53		N 146 E
	86 56.1	56.6	5.0	11.0			
34. Slope.....	272 02.2	02.7	11.7	5.3	229 55	22.3	N 148 E
	88 02.0	02.5	5.0	11.0			
46. Bay, valley.....					247 40		N 166 E
47. Peak	273 59.8	60.2	7.7	1.7	285 04		S 24 W
	86 01.3	01.8	7.0	13.0			
35. (not visible, pointed according to estimate) ...					320 35		S 59 W
48. Hummock	272 38.3	38.3	10.5	5.4	339 53		S 78 W
	87 23.1	23.5	8.0	14.0			
49. Peak	280 09.0	09.0	11.0	5.0	5 22		S 104 W
	79 52.4	52.4	3.8	9.7			
50. Peak	278 42.9	43.4	12.2	6.2	34 23		S 153 W
	81 18.8	19.1	2.7	8.7			
51. Tangent to the west side of the fjord.....					37 23		S 136 W perhaps N 56 E

[1]) See Fig. 51.

[2]) Misreading. The sum of the readings with "Telescope left" and "Telescope right" should be a little more than 360 degrees. Also the levelling of point 34 is doubtful.

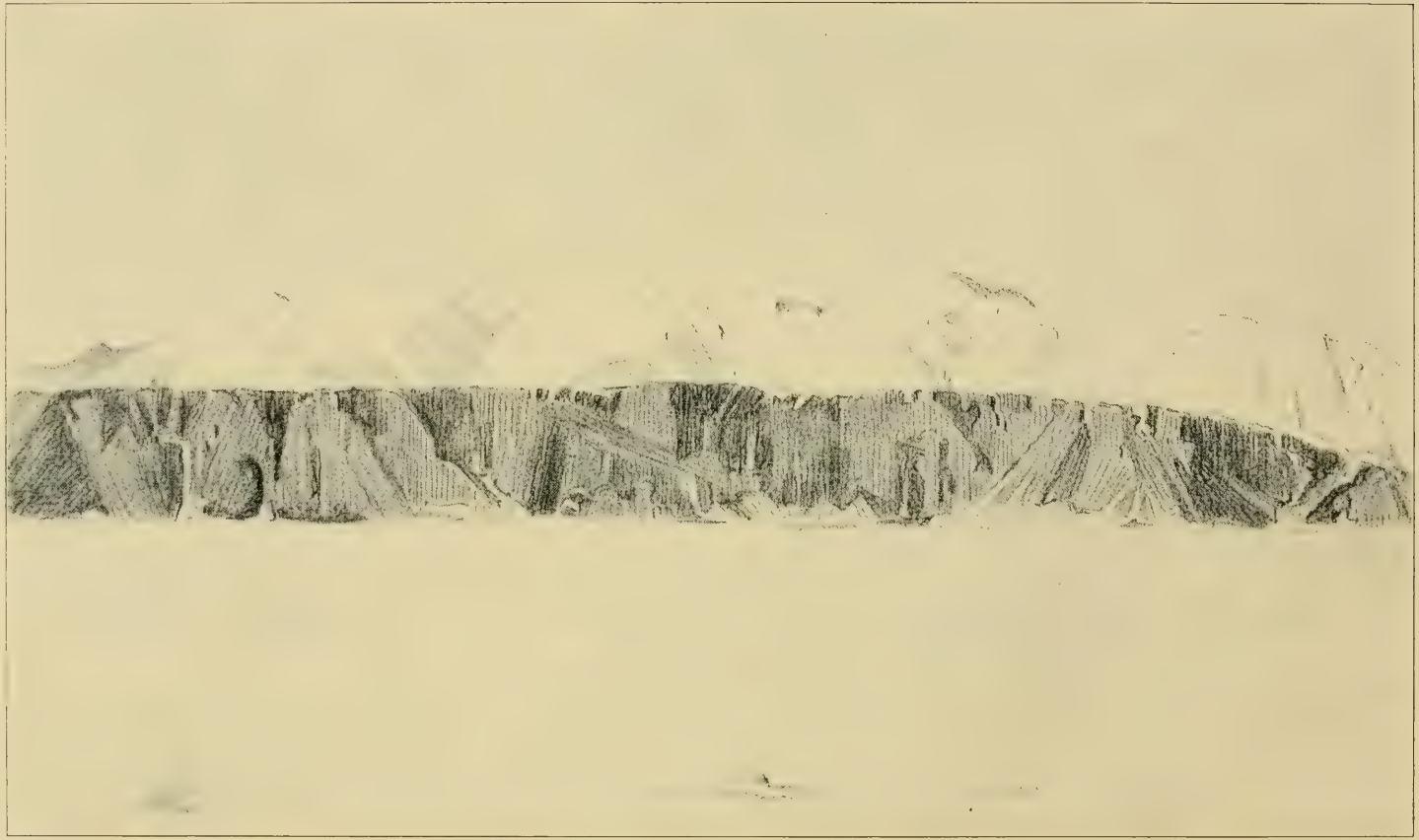


Fig. 53. View of Dannebrogstinde and Hundeskrænten seen from the north side of Fr. E. Hyde Fjord.
Drawn by Bertelsen from one of his paintings.

Station X. Determination of time 16/V, afternoon, ☋, b = 764.2, l = ÷ 12.0.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
6h57m35s	287°53′.1	53′.5	12.2	6.2	6h59m37s	72°11′.7	12′.2	3.0	9.0
7 01 10	46.9	47.3	12.2	6.2	7 02 50	17.2	17.6	5.3	11.4
04 13.5	41.6	42.0	11.5	5.5	05 31	21.6	22.2	5.5	11.5

Station X. Determination of time 17/V, forenoon, ☌, b = 771.8, 17/V
l = ÷ 11.5.

Chron. 57203 8h33m00s 8h33m30s
Watch K 5 53 50.0 5 54 20.0.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
6h09m45s	288°37′.8	38′.2	12.2	6.5	6h11m29s	71°20′.4	21′.1	2.8	8.5
14 01.5	44.8	45.2	11.5	5.7	15 38	13.8	14.2	3.5	9.2
17 28.5	51.0	51.2	11.2	5.5	19 29.5	06.2	06.6	3.5	9.2

Calm, cover of clouds 3, cumulo-stratus everywhere on the horizon. Probably fog out to sea.

Started at 8 a. m. We went across the fjord, in order to look 17/V
for a station on the south side, from which we could see the termination of the fjord. The ice on the fjord was pack ice; the snow had made long wall-like drifts, which were hard blown in the longitudinal direction of the fjord, and between which there was glare ice. After a very hard and warm journey we reached the country on the south side at 10.30 a. m. The hodometer gave the breadth of the fjord as 12 km. We were quite exhausted when we had crossed the fjord. The reason of this was, as far as BERTELSEN and especially I myself were concerned, lack of sufficient sleep in addition to the unaccustomed food. It was due to the observations to be taken whenever the sun was visible in the sky — at 6 in the morning, at 12 noon, at 6 in the evening and at midnight — that I could not lie down and sleep for more than 2—4 hours at a time, and even then with a constant fear that I might oversleep myself and so miss the observation, which, of course, made my rest less sound and valuable. But also the food played a certain part. The

sledge provisions, which we had in the first place computed for the sledge journey to Kap Bridgman was nearly consumed — milk, meat chocolate, butter, bread, cocoa, coffee, tea, blood pudding, sugar, lime juice — and all we had left was a little oatmeal, some pemmican and a tin of lobscouse. Consequently we were — and had already been for quite a long time — reduced to eating the still fresh meat of the musk oxen which the dogs had eaten of. We generally made soup twice a day, and besides we cut off raw meat for travelling provisions. Unfortunately we had to be very economical as regards petroleum; the meat was in reality never boiled, but only heated to the boiling point of the water. After a few days Bertelsen and I were rather tired of this diet, and though we — and in particular I — ate very much, we were still perpetually hungry. In short, we were exhausted, and after having pitched our tent and cooked our food — this time pemmican and pea sausage, and for once we were really satisfied — we turned in, that is, we lay down on our sleeping bags and slept, while Tobias drove to a valley to look for musk oxen. At about 5 o'clock Tobias returned. He had seen a lot of excrements and traces of musk oxen on the ground, as well as two fresh traces on the snow, but no oxen. Besides he had seen traces of foxes, of lemming and four hares, which the dogs had chased away. Later on we also several times heard the chirping of snow buntings.

Hyde Fjord, south side. Station XI.

Determination of latitude 17/V 07, Ω, $b = 769.5$, $t = \div 9.5$.

The determination of latitude is performed at the tent, i. e. west of the station. Hodometer distance from camping site 16/V 13 km.

Telescope left					Telescope right					424°15′.7
Watch K	Vernier		Level		Watch K	Vernier		Level		295 46.8
	A	B	Obs.	Obj.		A	B	Obs.	Obj.	128 29.4
										$z =$ 64°14′.7
										$\rho = \div$ 15.8
12h08m17s	295°46′.1	46′.6	7.6	3.0	12h10m11s	64°15′.4	16′.0	2.5	7.0	$r = +$ 2.0
12 38	46.1	46.6	7.3	2.7	14 16.5	15.4	15.9	2.5	7.0	$\delta = +19$ 08.6
16 06	46.0	46.5	7.0	2.3	17 53	15.5	16.0	3.0	7.5	$\varphi =$ 83°09′.5

The weather 17/V. In the forenoon and ás late as 5 p. m. calm, bright sunshine, light haze. At 5 p. m. rather violent gusts from NNE; still Bertelsen could sit in the open air and paint. These gusts of wind lasted till a little over midnight (about 1 a. m.), and during the last few hours they perhaps had the direction of NNW. From 1 a. m. again calm.

In this place Hyde Fjord bends a little, and then it continues, 18/V
as it seems, right through land, so that one would think it was connected with the sea towards west. It looks, unfortunately, as if we shall be obliged to leave this the most northerly fjord of Greenland unfinished; we have only provisions and dogs' feed for two, perhaps two days and a half, so that we are now obliged to return. I am quite sorry that I shall not be able to penetrate further into this glorious alpine fjord.

(Here follow pocket book sketches of traces of ptarmigan and wolves drawn by BERTELSEN).

Stone sample: granite[1]) with big grains of quartz, 320 m. Vein of quartz with layers of rounded pebbles. Extent of the vein 20 m. 6 layers of rounded pebbles of 1 cm, altitude above level of the sea 250 m. Perhaps here there is only primary rock[1]) with veins of quartz, as well as two kinds of conglomerate: one conglomerate with rounded pebbles, found in situ at 150—200 m, as well as a breccia with pebbles of granite, which I have only seen as blocks.

The vegetation was sparse. In the narrow depressions cutting into the land there was a good deal of grass, as well as *cassiope tetragona*, which even in places might form long continuous streaks, but the fell field itself was very desolate. It was all the more strange to come across traces of musk oxen and foxes, ptarmigan and wolf; the last trace was in snow and perhaps a week old. Besides TOBIAS has seen four hares as well as traces of lemming.

Station XI. Determination of time 18/V 07, forenoon, Ω, $b = 717.2$, $t = \div 8.7$.

South side of Hyde Fjord, altitude above the level of the sea about 550 m.

Chron. 57203	$9^h57^m00^s$	$9^h57^m30^s$
Watch K	6 53 42.7	6 54 12.7

Telescope left					Telescope right				
Watch K	Vernier		Level		Watch K	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$6^h59^m28^s$	290°21'.8	22'.5	10.0	5.0	$7^h00^m32^s$	69°37'.6	37'.9	7.0	12.0
7 01 53.5	26.3	26.9	11.0	5.8	03 02.5	33.0	33.3	7.0	12.0
04 17	30.6	30.8	11.0	6.0	03 48.5	28.0	28.6	7.5	12.5

[1]) Proved to be somewhat metamorphosed sedimentary rocks.

Determination of azimuth 18/V, forenoon, ⊕, $b = 717.2$, $t = \div 8.7$.

Watch K	Vertical circle Vernier A	Vertical circle Vernier B	Level Obs.	Level Obj.	Horizontal circle	Compass	Azimuth
Telescope left ..... $7^h07^m05^s$	290°35'.6	35'.9	11.5	6.5	29°15	156°.2	
Telescope right 08 37	69 23.1	24.9	4.0	9.0	29 41	157.4	N 103 E
Point in the terrain:	(see Bertelsen' sketches of 18. Maj 1907[1])						
32.	271°45'.3	46'.0	9.2	4.3	40°24'		N 114 E
	88 15.4	15.7	7.0	12.0			
33.	274 35.8	36.0	8.0	3.0	73 25		N 147 E
	85 26.7	27.0	7.0	12.0			
47.	273 02.8	03.1	11.5	6.5	175 18		S 69 W
	86 58.2	59.0	3.0	8.0			
Direction towards the tent, distance about 4 km					175 00		S 69 W
35. Approximate					195 30		S 89 W
37.	271 41.9	42.4	12.3	7.2	245 14		S 139 W
	88 19.4	20.2	5.5	11.0			
38.	271 39.9	40.5	13.5	8.0	252 10		S 146 W
	88 21.4	22.2	6.0	11.3			
23.	271 33.4	33.6	13.5	8.0	259 26		S 153 W
	88 29.0	29.5	7.0	12.0			
39.	271 11.0	11.0	6.2	1.0	270 15		S 164 W
	88 51.0	51.7	6.0	11.0			
52. Coast	269 18.5	18.8	8.5	3.5	203 17		S 97 W
	90 42.3	43.0	4.5	9.5			
53. Interior of fjord, coast	269 21.5	22.0	10.0	5.0	203 17		S 97 W
	90 40.3	41.1	5.0	10.2			
54. Coast, headland	268 56.3	56.6	11.5	6.5	212 19		S 106 W
	91 04.4	05.1	5.3	10.6			
55. Coast, rounding	267 40.8	41.0	12.0	6.7	240 17		S 134 W
	92 20.6	21.1	6.5	11.8			
49. Mountain	269 59.2	59.2	11.3	6.0	248 37		S 142 W
	90 01.7	02.6	5.0	10.5			
56. Station X					258 15		S 152 W
57. Headland[2]	268 46.3	46.5	8.0	2.8	307 11		N 21 E
(Pointing difficult)	88 24.6	25.0	7.6	12.8			
58. Outer headland					328 27		N 22 E

[1]) See Fig. 52.
[2]) Misreading in the levelling of 10'.

Barometric measuring of altitudes[1]) Station XI.

The altitude of the camping site above the level of the sea 5 m.

Ascension: At the camping site at 4.30 a. m. $b_5 = 766.6$, $t = \div 11.6$.
At the station 6.30 — $b_5 = 717.2$, $t = \div 8.7$.
Descent: At the station 8.40 — $b_5 = 719.3$, $t = \div 8.2$.
At the camping site 10 — $b_5 = 763.8$, $t = \div 12.3$.

[1]) At that time we had at our commaud only one barometer, and the measuring with the latter gave a poor result. The measuring of altitudes was supported by the levelling at Point 55, the distance to which was fairly well-known.

18/V in the forenoon took measurings from a station south of Hyde Fjord, at an altitude of about 500 m. It seems as if the fjord as far towards the interior, as could be seen from there, became narrower and thus presumably terminates in a small bend in a southwesterly direction; but we could not be quite sure of this.

When we returned from the tent, BERTELSEN's dogs had disappeared. They had gone with us to the mountains, and there I suppose they found a trace, which tempted them to give chase. It is a most annoying occurrence, as we have scarcely provisions enough for men and dogs to get back to our depot.

Stone sample 2. Hewn from a loose block, of which we found great quantities in the fell field at an altitude of 500—600 m; undoubtedly to be found in situ (the light grey stone in the peaks everywhere).

Stone sample 3, of the solid rock, height about 200 m.

Stone sample 4, conglomerate? or granite in situ with great grains of quartz; height 320 m.

Stone sample 5, the vein of quartz 250 m (see above).

Still in Hyde Fjord. BERTELSEN's dogs stayed away with the 19/V
exception of three, which turned up an hour after we had got down the mountains. Now we must necessarily risk something to recover the six missing dogs; the loss would be too serious, particularly as our best dog, Pedersen, was among those missing. In the meantime we decided to wait till midnight, 18—19/V to see whether the dogs would not return, driven by hunger. However, they did not come back. TOBIAS then volunteered to go and look for them. I should have liked to have gone myself, but my foot-gear was in such a poor state, that I did not dare to do so. As a matter of fact I had only one pair of very dilapidated komags (Laplanders' boots) left. BERTELSEN was ill; he suffered from nausea and sleeplessness in consequence of the monotonous food. Thus TOBIAS went and returned at 2.30 a. m. He had not seen the dogs, but he had found their traces, mixed up with those of a musk ox, and had seen that they went right across the 500 m high slope towards the fjord. The situation was easily explained; the problem was only what had been the result? We started at once — at 3.30 a. m. — and drove along the slope, hoping to get the solution of the problem. But the fog, which set in closely from the sea, did not augur well in this respect. Then after having driven 5 km we came across traces of dogs, and shorthy afterwards Pedersen came jogging along towards us, heavy and round-bellied; nearly at the same moment the dogs scented game and with bag and baggage rushed towards the slope, where they pounced upon the riven carcass of a musk ox. There

was nothing the matter with Pedersen, except that he was incredibly overfed — but the other dogs? Possibly they had perished in the breakneck leap, and now lay somewhere on that inaccessible rocky slope; but this hardly exhausted the possibilities. As we had now all at once become rather well-provided with dogs' feed, we resolved to wait for a day or two in order — if possible — to get hold of the five missing dogs. If we should become obliged to leave without them, we should still be able to get along; Pedersen alone was worth as much as the other five. Besides our dogs helped themselves so amply, that we should hardly be able to drive with them these twelve hours. Started from the last camping site at 3.30 a. m. Hodometer distance 5 km; third camping site in the Hyde Fjord 19/V at 4.30 a. m.

"The adventure has begun", said Bertelsen on the day, when we parted from Mylius-Ericksen, and he is right — this journey is an adventure. If only Bertelsen were well again, I would even call it a good and a beautiful adventure.

The weather. From 18/V 10 a. m. till 19/V 3 a. m. I never left the tent. I was exhausted, and slept almost without interruption. My weather report is consequently not very reliable. Until 3 p. m. calm, then gusts from NNW., which became a steady 5 m wind from NNW. This gradually shifted to NE. (the direction of the fjord) and on 19/V at 2 a. m. the fog began to drift into the fjord. At 8 a. m. the temperature $\div$ 15.5, the wind falls light; velocity of the wind now 2 m, NE, fog.

Whereas the slopes in the outer part of Hyde Fjord are rather bare of snow, this does not seem to be the case further inland, where the country still seems to be practically covered with snow. Behind the highest peaks in the interior of the country névés are visible on the southern side of the fjord, west of Point 47.

20/V 12.15 a. m. Started with twenty dogs. Hundeskrænten (The dogs' slope) 5 + 12 km long. At 5 a. m. reached the most northerly point of Skagen. Hodometer 28½ km. The wind, which in the fjord blew with 3 m from NE., blew outside the fjord with 2 m from WNW. Fog; very light fall of snow.

Skagen consists of steel-grey granite with strongly marked fluidal structure.

By and by the wind grew stronger; from 5 to 8 o'clock it rose to 5—6 m with increasing drift of snow. At the same time the sky cleared up a little so that the sun became more visible (it had never been completely obscured by the fog). Camped at 9 o'clock on the north side of the entrance to Schley Fjord. The snow drift was at that time rather considerable; the fall of snow had stopped. At 12

Fig. 54. Hundeskrænten.
Drawn by Bertelsen from one of his paintings.

o'clock, noon, velocity of the wind 8 to 10 m. The wind is here blowing along the shore i. e. northerly; it is to be supposed that it is more westerly out at sea.

Hodometer distance 54 km.

It was not without misgivings that we started to-night, without BERTELSEN's dogs, but we could not wait any longer. The journey to our depot would presumably take us four days, and we only had petroleum and provisions for two days. It is true that we might live exclusively on raw musk ox meat; but the loathing felt by BERTELSEN for this kind of food, and his illness which was undoubtedly due to the monotonous manner of living, made it extremely desirable for us to reach our depot as quickly as possible. I had partly the same symptoms myself: langour, loathing for food, nausea, constipation, perhaps also a little bit of vertigo and headache, but clearly in a much lesser degree than BERTELSEN. As, furthermore, TOBIAS was of the opinion that the dogs had killed themselves in the same manner as the musk ox, which supposition one was fain to entertain face to face with the slope, it would be wrong to remain longer in Hyde Fjord. As a last attempt I asked TOBIAS to drive the 5 km back to our former camping site to look for the dogs there, but though he did so immediately before the start, he found no dogs there. Then TOBIAS gave one dog and I another to BERTELSEN, so that we now were driving with seven, seven and six dogs respectively. In a somewhat depressed mood we shaped our course out of Hyde Fjord; BERTELSEN in particular, of course, felt the loss of half of his team very much; when all is said and done, one cannot help getting fond of those animals, which toil for one day after day, and are only rewarded with a bone and abundance of blows.

The dogs had however profited by the strong food and the previous days spent in comparative comfort; in spite of the reduced teams we made 54 km in nine hours and under conditions which were by no means particularly favourable.

Stone sample from the north side of the entrance to Schley Fjord. The sample is taken from a loose rock, but the stone was undeniably to be found in situ. I was less than 50 m away from the solid rock, but I could not get farther on account of my enfeebled state. The ground and practically the whole side of the mountain was everywhere strewn with blocks of this kind; besides we here and there found little bits of a steel-grey colour and of the same consistency.

The weather. Towards 8 p. m. (20/V) the wind began to subside, in that it now came in gusts. At 12 midnight, we had quite a faint wind from north (along the shore) with a light fall of snow and mist. However it seemed to clear up towards north.

21/V Started at 2.50 a. m. Calm; suggestion of snow fall, thick. West of Clarence Wyckoff, in the interior of Peary Land, we see a mountain range with peaks of about 2000 m covered with névés.

Peary's Cairn. Determination of time 21/V 07, forenoon, ☌,
$b = 768.0$, $t = \div 11.3$.
Hodometer distance from camping site 20/V 22 km.

Telescope left					Telescope right				
Watch K	Vernier		Level		Watch K	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
6h59m17s.5	291°26′.6	27′.1	12.0	7.3	7h00m30s	68°32′.6	32′.9	7.2	12.0
7 01 48	31.2	31.4	8.0	3.3	03 13	27.2	27.8	7.2	12.2
04 59	36.8	37.4	10.0	5.2	05 50	22.1	22.8	7.0	12.0
07 07	40.5	41.0	11.0	6.3	08 18	18.1	18.4	7.4	12.1

Thick haze; the limb of the sun dim during the first two observations; these are, therefore, only half as good as the last two.

Chronom. 57203	9h49m00s	9h49m30s
Watch K	6 53 46.8	6 54 16.8

"May 21st 1907 a. m.

"Reached C. Bridgman; stayed 3 days in the Hyde Fjord; lost "here 5 dogs going down over a precipice in pursuit of a musk-ox. "We are now going southward to Academy Land, 3 men, 3 sledges "and 20 dogs. Bertelsen and I suffer from not being able to digest "the musk-oxen meat; for several days we have had almost no other "food. I think we shall be allright again, when we the 23rd shall "reach our depot at 82°30′.

I. P. Koch."

Deposited the above at 7.30 a. m. in Peary's Cairn.

The small indentation south-east of Peary's Cairn has very nearly the following shape (Pocket book sketch).

The dogs seemed rather dull to-day; it was hard work to get them to make 47 km in spite of tolerably good sledding. Stopped at 1.50 p. m. Distance made 47 km.

During the whole day calm or perhaps faint variable winds. About 7 a. m. for a moment tolerably clear. About 3 o'clock the weather cleared up, though still with a little haze. Still calm. In the course of the evening and night again fog with calm. At 5 a. m.
22/V the sun began once more to penetrate the fog.

Now our petroleum is used up, and we shall only get raw meat for the remainder of our journey to our depot at 82°30′. This would

be of no importance, if BERTELSEN and I did not suffer from constant constipation and were extremely exhausted. Yesterday we tried to get salt water as an aperient, but we failed, as the palæocrystic ice in this place is quite fresh.

Started at 7.30 a. m. Our camping site was here a little to the north of the great valley south of Clarence Wyckoff. The coast here falls ESE; level banks in the sea near the coast.

On the eastern part of Herlufsholms Næs the snow lies in great, smooth sheets, which on large stretches cover everything, and beyond which one sees quite an even snow-horizon. Not till quite near the coast does the rubbled gravel crop up again like small islands. The snow is loose, fresh-fallen snow; in a single place, however, in a crevice where the wind had made a large "whirling cauldron" [1]) we could clearly distinguish a stratification of the nature of névés.

It seems as if a good deal of snow has fallen on the mountains in the course of the night; they are much whiter than yesterday.

On the march to-day we soon left the sea ice and drove across the snow-covered Herlufsholms Næs, where before very long we came across quite fresh traces of a herd of musk oxen. The dogs got hold of the scent and set off at a gallop, without heeding the snow-bare spots, so that sparks flew from the sledge runners, and the sledge irons suffered a good deal. After a while we discovered a solitary bull at a distance of a few hundred metres from us. It was too tempting, for though we thought we had sufficient meat for the dogs in the meat depot, it was tainted, and so we could very well make use of this solitary gentleman. BERTELSEN and I were exhausted, and so did not wish to take part in the hunting. Consequently TOBIAS went off alone and returned after an hour and a half with the bull on the sledge. He had shown the good sense to cut off its head, and the entrails had been removed.

Our intention to go to the meat depot and from there to the sledge box depot was altered, as with the heavy sledding across land we could not carry all the meat; instead of that we decided to go direct to the sledge box depot, which lay at a distance of about 17 to 18 km. It was of great importance for us to reach the sledge box depot, where we could get pemmican and melt salt ice, so as

[1]) Whirling cauldrons with stratification and snow partaking of the nature of névés was an infallible sign of the existence of an ice grotto of a similar kind to the Gnipa Cave. "Whirling cauldrons" of this kind we knew from the neighbourhood of Danmarks Havn, but we did not know at the time that they were a phenomenon indicating ice grottos. When first we found dents of this kind in the snow and the névés, we thought that they were due to standing vortices of air, caused by local topographic conditions; hence the designation "whirling cauldrons".

to be able to recover from an illness, which under these circumstances hampered our movements and depressed our spirits.

The weather on 22/V. In the morning and the forenoon a light mist; the sun visible, calm; now and then a faint suggestion of snow fall. At 2 p. m. wind from WSW, thick with snow (the greatest snow fall we had hitherto had on the journey, though trifling in itself). From 2 p. m. to 5 p. m. the wind rose to a velocity of 5 m,
23/V and little by little shifted to NW. 8 p. m. wind 8 m direction north, still thick with snow. The wind continued with a fall of snow and a considerable drift till 23/V, after that it gradually fell off; at 6 p. m. 23/V calm. Constant mist and haze. Yesterday and to-day the temperature has been unusually high, though it has not been measured. The snow which fell on our sleeping bags during the drive yesterday melted.

The heavy fall of snow served us rather a nasty trick; in the thick weather we overshot the sledge box depot. I realized this, when we had driven about 20 km; our course must now be too southerly and consequently also too westerly, as we must otherwise have reached the sea ice; but Tobias, deceived by the fact that the wind had shifted from WSW to north, thought that our course was far too easterly. So he wished to drive towards SW, whereas I wished to drive towards SE. Our uncertainty was thus sufficiently proved, and as the dogs were furthermore very much exhausted by the 40 km journey across land, I resolved to camp where we were, in order to await an improvement in the weather conditions. Stopped 22/V at 9 p. m.

In order to get away from our extremely forward dogs, we dragged the musk ox into the tent, where we skinned and quartered it. At 2.30 a. m. (23/V) we turned in, having got no other food during the last thirty-six hours than a little raw frozen meat and some raw marrow. We tried to eat the fresh warm liver raw, but it made us feel sick. We could not even get any water, but had to content ourselves with eating a little snow.

23/V the weather was thick, but the wind and consequently also the snow drift abating somewhat at noon, Tobias thought we ought to start. He was undoubtedly right in this, but it now turned out that the trifling effort to rise gave me rather a bad fever; besides I was very tired. Bertelsen had apparently not suffered quite so much from the constipation and the fasting cure, but was also rather bad. We tried to brace ourselves with twenty-five drops of essence of camphor, but it did not help me, and consequently I asked Tobias to wait a little and then drive alone with an empty sledge to the depot to fetch the things we required, that is, petroleum

and salt ice as well as the sledge box and spirit. At 4.30 p. m. TOBIAS left. The weather was then somewhat clearer. At 7 p. m. he returned. He had found the depot in northeast, at a distance of nearly 7 to 8 km. Unfortunately he had not been able to get hold of salt ice; just as farther north all the ice here was entirely fresh palæocrystic ice. BERTELSEN and I each drank a pint of boiled water, ate oatmeal porridge and stewed prunes, and hoped that we should now get better.

In the report[1]) something must be said of the value TOBIAS was to us on this trip: his knowledge of ice, dogs, sledges, hunting conditions, of the use of the meat of musk oxen, their sinews and hides, his skill in working with primitive means &c&c. and with all that a good and loyal friend and comrade.

8.30 a. m. Temperature ÷ 9.0. Fog. Light fall of snow. Fetched the meat depot; BERTELSEN enema.

Started at 8.30 a. m. to fetch the meat we had in depot. Haze 24/V
and fog, though we were able to distinguish the mountains and therefore with good cause hoped to find our depot. Before the start I had a very fair motion and felt very much relieved; on the other hand the boiled water had had no effect on BERTELSEN. I had then decided on the rather original experiment of giving BERTELSEN an enema, by means of the petroleum funnel and a jug. The funnel, which WEINSCENK had made for us, I first of all filed off very carefully, so that all sharp edges were rounded off, and after that I gave BERTELSEN an enema amounting to nearly a quart of the lukewarm water. It was rather an easy way, and had an immediate and good effect.

But still we were very tired, when after a few hours we found our depot, and here a rather stiff job awaited us. It is true that the foxes made frequent visits to the place — one blue fox fled, when we arrived — but they had only gnawed bits of hide, the heads and similar things, and had left the depot quite intact. But the meat in the one pit, and that the greatest, was frozen solid into one big lump, which for the time being we could not quarter, as we had no axe. So we had to load the whole lump on TOBIAS' sledge and harness ten dogs to it. When towards the middle of the afternoon we returned to the tent, I was quite exhausted and unable to travel further; besides we had many hours' work left with the big lump of meat. We set to work cutting it up, and in the process we unfortunately broke the handle of our axe twice, which loss may perhaps not be remedied in this place, and which may prove very

[1]) Here I am thinking of the official report of the journey, which was to be written after our return. See Medd. om Grønl. XLI, pp. 139—140.

disagreeable to us. Tobias works like a horse, but then he has nearly also to work for three.

The weather. At noon it cleared up; the sun burned through and baked terribly. Calm. The clear weather lasted during the whole afternoon.

25/V This morning I have, together with Bertelsen and Tobias, gone over the prospects of our return. The case is as follows:

In three days i. e. 28/V we may leave Peary Land with well fed dogs and carrying

provisions for 10 days,
dogs' feed - 13 —
petroleum - 20 — [1]).

The journey to Nordre Depot Ø may be supposed to last twenty-one marches, and during this period our supplies will be increased by provisions for five days and dogs' feed for six, as well as ample petroleum. Thus we shall lack:

Provisions for 6 days,
Dogs' feed - 2 —

This can hardly be called unfavourable, as long as the sea ice is still there so that we may proceed, and when Bertelsen and I recover our strength. I also suppose we may count on a couple of bears and perhaps also on a good number of fulmars.

Our thoughts constantly recur to the first sledge party who went west[2]). Have they got musk oxen? Do they suffer the same hardships as we? Are they still up here in Peary Land, or have they perhaps returned long ago? In a week, when we arrive at one of the old camping sites, we shall perhaps get news of them.

11.15 a. m. Started. Passed several fresh, unmistakeable traces of lemmings in the snow on land. Course SSE. Reached the shore after 6½ km. Continued along the shore. 1.30 p. m. Course SSW.

A lot of snow has fallen during these last few days; there is 1 to 2 decimetres of loose new snow on top of the old one, and it hampers the sledge badly, so that we are crawling along. A little

[1]) According to the list on p. 315 we had on 1/V petroleum for twenty-five days. When now from 28/V we might reckon on being supplied for twenty days, the reason was partly to be looked for in the fact that we had only used very little petroleum on Peary Land, partly that the temperature would rise from now onwards, so that we should scarcely have to reckon with having to melt ice and snow.

[2] Mylius-Erichsen, Hagen and Brønlund. This sledge party were at the time staying in Danmarks Fjord, the existence of which we could at the time know nothing of.

storm would be very useful, but now, when we could use it, I suppose we shan't get it. The country is not to be recognized. When we arrived here eighteen days ago, it was bare and brown and tempting; now it is everywhere covered with a cold carpet of snow. But the sun is baking incredibly, and perhaps it may also help us by making the snow disappear. It will last a couple of days, and with that time we ought to be on the other side of the bay[1]).

As regards our health we are progressing fairly well. However, towards 5 p. m. I again became feverish, and therefore stopped at 6 p. m. Hodometer distance for to-day 22 km. TOBIAS, who had gone to fetch the goods, left at the depot, arrived at the camping site at 6.30. To-night we had a meal consisting of boiled milk and rye biscuits, the most delightful meal I have had for a long time. After that BERTELSEN was again given an enema, which had an immediate effect. The dogs are satiated; to-night they can only eat very little.

Determination of time 25/V 07, afternoon, ☉, $b = 769.3$, $t = \div 11.3$.

Chron. 57203	$21^h40^m00^s$	$21^h40^m30^s$
Watch *K*	6 26 51.4	6 27 21.4.

Telescope right					Telescope left				
Watch *K*	Vernier		Level		Watch *K*	Vernier		Level	
	A	B	Obs.	Obj.		A	B	Obs.	Obj.
$6^h29^m03^s$	289°42′.2	42′.7	12.1	6.9	$6^h30^m41^s$	70°21′.8	22′.8	3.0	8.3
31 49	36.7	37.0	12.1	6.9	33 02.5	26.2	27.2	3.0	8.2
34 27	31.8	32.3	11.6	6.3	35 29	31.1	31.7	2.0	7.3

Determination of azimuth 25/V, afternoon, ⊕, $b = 769.3$, $t = \div 11.3$.

Watch *K*		Vernier		Level		Horizontal circle	Azimuth
		A	B	Obs.	Obj.		
Telescope left.....	$6^h37^m23^s$	289°26′.3	26′.6	12.1	6.0	25°11′	N $76^1/_2$ W
— right	39 47	70 39.5	40.4	3.3	8.6	25 49	
Point in the terrain:							
Tangent to land in south ...						287°02′	S 2 W
— - nearest headland.						312 25	S 27 W
Point 14/I (?)						90 59	N 11 W

Cover of clouds 2, stratus in west, calm.

[1]) Independence Fjord.

Determination of latitude of 25—26/V 07, midnight, ☋, $b = 769.0$, $t = \div 15.2$.
Culmination clock time about 12.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
12h02m35s	283°40′.8	41′.2	12.2	6.0	12h05m45s	76°19′.8	20′.5	3.0	8.4
09 00	41.2	41.7	8.5	2.0	12 00	19.2	19.8	5.0	10.5
17 50	42.9	43.2	10.2	4.6	21 20	17.6	17.8	8.0	13.5

436°20′.2
283 41.0
152°39′.2
$z =$ 76°19′.6
$\rho = +$ 15.8
$r = +$ 3.8
$\delta = +$ 20 53.6
97°32′.8
$\varphi =$ 82°27′.2

Cover of clouds 1, stratus beneath the sun; calm.

The determination of latitude seems to have failed altogether, though the reason of this cannot be decided.

1.30 p. m. Started. Course towards south. The going terribly[1]) heavy. Tobias and I used our skis to great advantage. Stopped at 11 a. m. after having covered a distance of 27.5 km.

The weather: cloudy during the whole of the journey; cover of clouds 6—8, cumulus. The wind variable, velocity 0—2 m. Towards 9 p. m. it began to look like a storm. The wind became northerly, but the storm did not break. In the course of the night a light
27/V snow drift.

Bertelsen and I are still unwell, though I think I am recovering a little, but I am terribly tired. Besides my gums are sore so that I have great difficulty in chewing this beastly musk ox meat, which circumstance, of course, does not improve my digestion. Also Bertelsen and I are suffering from itch, Bertelsen all over his body, I across the loins[2]). Tobias is a little snow blind to-day; I hope he will soon recover.

Determination of time 27/V 07, afternoon, ☋, $b = 782$, $t = \div 9$.

Telescope left					Telescope right				
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.
4h55m43s	293°08′.9	09′.3	10.5	4.2	4h56m56s	66°55′.1	55′.7	6.5	12.5
58 26	03.1	03.7	9.0	3.0	5 00 27	67 02.0	02.8	5.0	11.0
5 01 48	292 57.2	57.5	11.0	5.0	03 09	07.0	07.5	5.0	11.0

[1]) This strong expression is only justified, when one makes allowance for the fever and our otherwise weakened condition. We drove on unbroken, smooth ice, covered with deep, loose snow.

[2]) At the time we thought that this itching was due to our illness, and so we did not at once investigate the matter. A few days afterwards we discovered that we were very much infested with parasites.

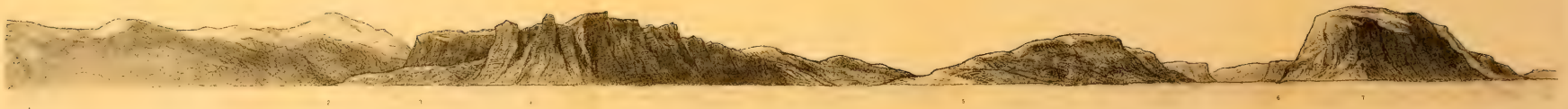


Fig. 55. View of Teufelkap and Surroundings seen from the west coast of Store Koldewey
distance about 30 km
Drawn by Aeatsuk Petit, September 28th 1906.
1 = Foenbugt 2. Viviani Fjeld 3. Tomnæsen. 4. Orgelgebeme
5. Bulgen 6. Hundeleiden 7. Teufelkap

Velocity of the wind 4 m, WSW. Cover of clouds 1, stratus, haze.

Chron. 57203	$20^h38^m00^s$	$20^h38^m30^s$
Watch *K*	5 16 59.7	5 17 29.5.

Departure 5.20 p. m.

10.30 p. m. Distance covered 17.5 km. The land[1]) which is now distant from us by about 1 km, has a levelly extending coast line towards north. Towards NE steep slope[1]), about 200 m high, with sandstone crags. Faint tidal pressure ridges along the shore. Course SSE.

After having covered a distance of 20 km, we quite unexpectedly came across Mylius-Erichsen, northward bound. This meeting caused us to camp together.

The geographical survey of Dove Bugt.

The most important of the stations determined by means of trigonometric station pointings are given in Fig. 32. With these practically all the more remote stations in Dove Bugt are connected by means of one or more sights, together with astronomical determination of the position. In this manner a much greater accuracy has been obtained as regards the chartographic material of Dove Bugt than is generally attainable in a geographical survey. This not only holds good as far as the determinations of the stations are concerned, but also as regards the sketching survey.

The geographical sketching survey in Dove Bugt was at a great number of stations performed by means of a vertical base. The altitudes of the stations, generally determined by means of a trigonometric levelling at points, the altitude of which was beforehand well determined, are characterized by a considerable certainty.

In order to give an impression of the survey work at Dove Bugt, I shall below give an extract of observations performed from Station XXIV, Teufelkap. This station is the highest and most important of all the stations at Dove Bugt, and it is in so far not a typical one. The observations from this place, however, furnish certain interesting details, owing to the conditions under which they were performed, and the manner in which they were carried through. The determination of position at Teufelkap is furthermore of special interest, in that it enters into the determination of the position of Haystack (see chapter II, the Position of Haystack, pp. 237—240).

The station at Teufelkap was measured 31/V 1908. As the mountain is inaccessible at the outer part towards Dove Bugt,

[1]) The land between Danmarks Fjord and Hagens Fjord.

[2]) Kap Rigsdagen.

Bistrup had to make a considerable detour in order to climb it. The height of the mountain is 875 m; the ascent was difficult; the mountain was at its upper, dome-like part covered by a water-filled névé, which one could only cross with great difficulty.

When Bistrup reached the highest peak of the mountain, he realized that it would mean considerable labour in observations, and also that the latter, owing to the position of the mountain, would require two stations. Bistrup was, however, already then so worn out with the ascent, that he had of necessity to perform the work in the easiest manner possible.

Bistrup's pocket book contains the following notes of the conditions, under which the measuring was performed.

"After several days of fog and wind we got clear and calm "weather 31/V. We left the tent at 5.45 a. m. and reached the peak "at 9.15. It was then too late to make a determination of time, and "as I was quite sure that I could see the Cairns XV and VIII and "with less certainty Cairn VI, I began a trigonometric station pointing "by means of XV—VIII—VI—Haystack — Peak C in Besselbay — "and a remote discernible peak which I suppose to be one of the "trigonometrically determined points of the Germans. At the beginning "of the observations the weather was almost calm, but the wind "increased more and more, and our position became extremely dis-"agreeable, and the more as we were very wet owing to our wading "in loose snow up to our hips. I at once gave up building the cairn, "as everything was covered with snow, and only a few stones pro-"jected from it. The observations I dared not put off for fear of fog; "there was a good deal of fog across Koldewey and Stormbugten, so "that I could not know, when it might begin to hamper my move-"ments. Therefore I could not make sketches from the two stations, "nor was it strictly necessary, as most of the points, mountains &c. "had already been sketched from other stations. Dronning Louises "Land was not visible throughout its whole extent; only a few peaks "were discernible; the rest were mixed up with each other, so that "on a drawing it would not have been possible to make anything "out of it. The distance was too great, the light was not good and "the air not clear. At a single spot I thought I saw the inland ice "behind Dronning Louises Land, but I am not sure."

In reality, of the six points mentioned above as serviceable for the station pointing, only the positions of the three cairns XV, VIII and VI were known, and even then it was doubtful, whether the last mentioned cairn could be seen. It was, therefore, necessary to perform an observation of latitude and azimuth, in order to obtain a control of the observation. The observations after this included:

Determination of latitude,
Determination of time and azimuth,
Trigonometric station pointing,
Sketching survey.

Besides a barometric levelling ought to have been performed, but the barometer and thermometer were not read off at all; why I don't know.

Determination of latitude.

Telescope left					Telescope right					
Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	
10h24m18s	315°15′.0	17′.5	10.5	2.5	10h23m10s	54°43′.0	45′.5	3.0	11.0	Ω
27 03	15.0	17.5	10.5	2.5	25 27	43.0	45.5	3.0	11.0	Ω
29 49	47.0	49.5	10.0	2.0	28 10	11.0	13.5	3.5	11.2	ʊ
32 42	46.5	48.5	10.0	2.0	31 39	11.5	14.0	3.0	11.0	ʊ
35 28	14.0	16.5	10.5	2.5	34 22	44.0	46.5	3.0	11.0	Ω
37 52	13.0	15.5	11.0	3.5	36 36	45.5	48.0	2.5	10.5	Ω

The temperature may be estimated at 0, the pressure at 680 mm, A provisional computation of the second and third pairs of observation gives

z		54°28′.0
Level	÷	0.2
Refr.	+	1.3
π		0.1
Geocentric z		54°29′.0
δ	+	21 54.5
φ		76°23′.5

This rough and ready computation of the latitude is in this case sufficient, because the temperature and pressure are not measured, for which reason the refraction cannot be determined with the necessary certainty.

Observation of time and azimuth (temperature and pressure as above).

	Watch K	Vernier A	Vernier B	Level Obs.	Level Obj.	Horizontal circle I	Horizontal circle II
Telescope right ..... ⊕	12h54m19s	57°17′.0	19′.5	4.0	12.0	172°34′.0	34′.0
— left..... ⊕	55 43	302 38.5	41.0	9.0	1.0	172 56.5	56.0
— right ..... ⊕	57 09	57 54.5	57.0	4.5	12.5	173 20.5	20.5
— left..... ⊕	59 09	301 59.5	61.5	9.0	1.0	173 52.5	53.0

Of the two pairs of observations we get as a mean

z	57°38′.4
Level..... +	0.5
Refraction ..... +	1.5
π ..... ÷	0.1
Geocentric z ..	57°39′.3

with the corresponding mean of the readings on the horizontal circle 173°11′.3.

The clock correction not being known beforehand, the azimuth is computed from the zenith distance.

In this manner we get:

a ..... +	42°26′.6
Horizontal reading	173 11.3
Meridian point.	130°44′.7 (see the control of the station pointing p. 358)

Station pointing. In the table below the results of the observations at Haystack, Peak C and Remote Peak are left out as being of no importance, as far as the computation is concerned. On the other hand both of the observations performed in the case of Cairn VI are included, seeing that as a precaution both of them were computed. In his observation journal Bistrup writes of these measurings: "Two points are sighted as Cairn VI, but it is, I suppose, the former which is the right one". As it will appear, Bistrup was mistaken.

Among other things, out of regard to the interest attaching to the corrrct determination of the position of Teufelkap, the computations are here to be given in all details.

The angles are measured in three sets, the mean values of which, in the case of the levellings with level corrections applied. is given below:

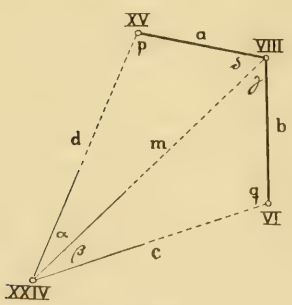


Fig. 56.

		Horizontal circle	Zenith distance	
Cairn	XV	330°17′15″	91°04′.9	
—	VIII	353 55 20	90 47.0	
—	(VI)	18 45 25	89 58.1	condemned, wrong point
—	VI	18 40 13	89 58.1	

Given for the computation are further (see Fig. 56 as well as p. 232 and p. 235).

The side XV—VIII = a =	17992 m
The side VIII—VI = b =	19554 m
Azimuth VIII—XV	99°34′06″
Azimuth VIII—VI.....	358 35 02
Hence $\gamma + \delta$...	100°59′04″

The heights of the cairns XV, XVIII and VI are 252.9 m, 393.2 m and 970 m respectively.

(For explanation of the computation table see p. 223).

$\gamma + \delta$	100°59′04″	$\log \tan u$	9.98263	u	43°51′17″
$\alpha + \beta$	48 22 58	$-\tan(45° \div u)$	8.30085	$45° \div u$	1 08 43
$\alpha + \beta + \gamma + \delta$	149 22 02	$-\tan \frac{1}{2}(p+q)$	0.56243 n	$\frac{1}{2}(p+q)$	105 18 59
$\frac{1}{2}(\alpha + \beta + \gamma + \delta)$	74 41 01	$-\tan \frac{1}{2}(p \div q)$	8.86328 n	$\frac{1}{2}(p \div q) \div$	4 10 29
$\frac{1}{2}(p+q)$	105 18 59			p	101°08′30″
				q	109 29 28

		log sinus	log side	
δd	55°13′25″	9.91455	4.56659	
$p m$	101 08 30	9.99174	4.64378	
αa	23 38 05	9.60304	4.25508	$\log(a : \sin \alpha)$ 4.65204
γc	45 45 39	9.85518	4.52459	
$q m$	109 29 28	9.97437	4.64378	
βb	24 44 53	9.62183	4.29124	$\log(b : \sin \beta)$ 4.66941

1. control of the computation: $\gamma + \delta = 101°59'04''$.
2. control of the computation: $\log \tan u = \log \sin q \div \log \sin p = 9.98263$.
3. control of the computation: $\log m = \begin{cases} 4.64378 \\ 4.64378 \end{cases}$.

Computation of geographical co-ordinates. As mentioned in the preceding Bistrup in the course of the station pointing sighted two points lying near one another, the angular distance of which, seen from Teufelkap, was only about 5′. Cairn VI stands on a low, dome-like hill, which only rises very little above the immediate surroundings. Quite a similar hill of the same altitude is found immediately south of the cairn. It must, therefore, a priori be supposed that the most northerly of the two sighted points was the right one; from Bistrup's note in the observation journal, however, just the opposite had to be inferred. The applying of a control to the observation was consequently most desirable. This can be obtained through the computation of the geographical co-ordinates of Station XXIV, in that one gets, in this manner, a value of the azimuth XXIV—VI, which can be compared with the result of the azimuth observation by the sun, performed at Station XXIV.

The explanation of the designations used in the computation table below is to be found on p. 234.

The computation has been performed from Station VI. For this point are given (see pp. 236 and 232):

$\varphi = 76°29'45''.6$, $l = 19°05'22''.1$, Azimuth VI—VIII = 178°36′07″

$\log(\text{VI}-\text{XXIV}) = \log c = \log K = 4.52459$ $\quad \angle q \ldots\ldots = 109\ 29\ 28$

Hence Azimuth VI—XXIV = z = 69°06′39″

$[1]\,m$	8.50858	$[2]_0$	8.50843	$s = +\ 384''.9 = +\ 6'24''.9$	$\varphi_0 = 76°23'20''.7$
K	4.52459	K	4.52459	$\theta = +4283''.5 = +1°11'23''.5$	$\sigma =\ 10''.2$
$\cos(z \div 2\gamma)$.	9.55214	$\sin(z \div \gamma)$.	9.97048	$t = +4163''.3 = +1°09'23''.3$	
v	3.0035	$[3]_0$	4.3847		
$\frac{1}{6}\omega$	3.9079	t_0	3.6195		
γ	9.4962	σ_0	1.0077		
$\gamma = +0''.31$					

v	3.00350	v	3.00350	c 3.9298	c 3.9298
$\sec\varphi_0$	0.62836	$\tan\varphi_0$	0.61600	t_0^2 ..... 7.2390	v^2 ..... 6.0070
θ_0	3.63186	t_0	3.61950	ct_0^2 ..... 1.1688	cv^2 ..... 9.9368
$\div 4\,ct_0^2$	$\div 6$	$\div 4ct_0^2 \div 2cv^2 \div 6$		$ct_0^2 = 14.8$	$cv^2 = 0.9$
θ	3.63180	t	3.61944		

Result for XXIV: $\varphi_1 = 76°23'10''.5$, $l_1 = 20°16'45''.6$, azimuth XXIV—VI = 247°57'15''.

The controlling computation from Cairn VIII gives the result:

$\varphi_1 = 76°23'10''.5$, $l_1 = 20°16'45''.6$, azimuth XXIV—VIII = 223°12'20''.

The difference between the two azimuths XXIV—VI and XXIV—VIII should be equal to $\angle\beta$, it deviates 2'' from this, which may be explained as a consequence of the uncertainty of the computation. The controlling computation is thus satisfactory.

The control of the observation is, as mentioned above, obtained through a comparison with the azimuth of the sun. From this one gets (see p. 356)

Meridian point in the circle	130°47'.7
Further: reading for Cairn VI....	18 40'.2
Azimuth XXIV—VI...	247°55'.5

This corresponds so well with the azimuth computed through the triangulation net, as one is at all entitled to expect from the manner in which the azimuth by the sun has been observed (pointing of the centre of the sun; temperature and pressure not measured).

After this it is hardly justifiable to entertain any doubt as to the fact that the northernmost of the two points for Cairn VI is the right one. Still I have as a precaution carried out the computation of the station pointing and of the geographical co-ordinates for the southernmost of the two points for Cairn VI, and in that manner one gets:

Azimuth XXIV—VI, computed geodesically ..	248°19'16''
Azimuth XXIV—VI, computed by means of an observation of the sun	248 00.4

The difference is here nearly 19′, which even at a rough and ready azimuth observation, under unfavourable conditions, would be an extremely grave error.

In this manner the last doubt as regards Cairn VI is removed.

Sketching survey at Station XXIV.

Determination of altitude of telescope.

	Cairn XV	Cairn VIII	Cairn VI
H_0	252.9	393.2	970
$\div D \cot z$	+ 696.0	+ 602.0	÷ 18.5
Refraction & curvature of the earth	÷ 80.1	÷ 121.6	÷ 70.0
H	868.8 m	873.6 m	881 m

As a mean we get the altitude of the telescope 875 m.

The sketching survey from Station XXIV comprises 132 points.

Below I will give an extract from Bistrup's observations as regards the sketching survey, as well as of my computation. To understand the designations of the table it must be borne in mind that the map is drawn to Mercator's cylindrical projection, that for the loxodromic azimuth I have used the convenient, but less correct designation "course", and also that by v I wish to designate the angle of depression.

Extract

Station XXIV, Teufelkap, 31/V 1908. H = 875 m.

No.	Point	Horizontal circle	Vertical circle	Azimuth	Course	tan v	Distance km	Height m
	Meridian point of the circle.	130°43′.0						
16	Store Koldewey, coast	47 10	91°33′.0	÷ 83°33′	÷ 83°.0	+ 0.0272	35.0	
38	Kap Peschel, coast	101 26	92 33.0	÷ 29 17	÷ 29.1	+ 0.0447	20.2	
39	Skerry	101 05	93 18.5	÷ 29 38	÷ 29.4	+ 0.0579	15.4	
40	Coast west of Kap Peschel	106 57	93 03.0	÷ 23 46	÷ 23.6	+ 0.0543	16.7	
41	Coast west of Kap Peschel	106 53	93 15.5	÷ 23 50	÷ 23.7	+ 0.0570	15.6	
44	Skerry	112 27	93 38.0	÷ 18 16	÷ 18.2	+ 0 0632	14.1	
48	Coast at glacier	131 50	92 58.0	+ 1 07	+ 1.1	+ 0.0518	17.2	
49	Coast at glacier	133 55	92 50.0	+ 3 12	+ 3 2	+ 0.0495	18.1	
54	Eastern point of Orgelpiberne	142 39	90 41.5	+ 11 56	+ 11.9	+ 0.0122	11.9	739
55	Peak K, also pointed from XIX	160 55	89 44.0	+ 30 12	+ 30.0	÷ 0.0043	21.1	995
58	Peak No. 3 a from XX	194 57	89 48.5	+ 64 14	+ 63.5	÷ 0.0032	c.51	1200
64	Peak west of Soranerbræ, No. 8 from XVIII	216 36	89 58.5	+ 85 53	+ 85.1	÷ 0.0003	39.3	984

The meridian point of the circle which by means of an observation of the sun was determined at 130°44′.7 is in the table given as 130°43′.0; the correction is due to the result of the geodesically computed azimuth.

Azimuths and "courses" are computed from the south, positive towards west, negative towards east. As the compass line between two points (the course) on the northern hemisphere is always more southerly than the great circle between the points, a small practical facilitation is effected, in that the angle indicating the compass line must always be numerically smaller than the one indicating the azimuth.

The correction from azimuth to "course" is made by the formula $d = \frac{d_l}{2} \sin \varphi$[1]), where d is the correction sought, d_l the difference of longitude between the station and the point measured at, and φ is the latitude of the station. As in this case $\sin \varphi$ is very near 1, d may with sufficient accuracy be put at $^1/_2 d_l$ taking d_l from the working map by laying down at an estimate the point in the latter. The zenith point correction is $+ 0'.5$. The values of $\tan v$, which are taken from a four-placed table of the numerical values of the tangent function, are determined by $v = z \div 90$, where z equals the reading off on the vertical circle $+ 0.5$.

The column of distances in kilometres is, as far as the coast points are concerned, filled in according to a computation of the distance by means of an engineer's scale in the manner indicated on pp. 304—307. As far as the other points are concerned, the distances are determined by intersection of bearings and taken from the map.

After that everything is ready for the final laying down of the points in the working map, which is done with a good station pointer. As the scale in the cylindrical projection of Mercator may vary very much, it would be a practical proceeding to have the frames of the working map arranged beforehand with a division in kilometres, side by side with the division in minutes of latitude.

The levellings.

A fairly reliable determination of the heights of mountains is one of the most difficult tasks in the execution of a geographical survey, and in many cases the difficulties are of such a kind that they cannot be surmounted at all — in any case not in a fairly satisfactory manner — under the conditions in which the observations take place. As far as the reliability of the map is concerned, it is, therefore, of great importance for one to keep one's critical faculties alive, in particular as regards the results of the levellings. As to the altitudes of the stations, from which the observations are performed, it will generally not be difficult to get a fair estimate of the accuracy, but as to the points determined by bearings and levellings from the

[1]) K. V. Ravn: Lærebog i Opmaaling I, pp. 46—40.

stations there may be some difficulty. For these points the chief sources of errors in the altitude are the following:

1. Errors in the determination of the position of the station.
2. Errors in the altitude of the station.
3. Ill-defined sighting points.
4. Variable refraction.

ad 1. Errors in the determination of the position of the station entail errors in the position of the points, the distance to these from the stations thus becoming wrong. In the case of favourable bearings this source of error does not play any great part, whereas at acute bearings it may exercise considerable influence.

ad 2. When during a coast survey the height of a station is determined by barometric observations from the surface of the sea, one will in that manner generally have guarded oneself against serious errors. If, however, one leaves the coast for a longer period, such as for instance we did during the two sledge trips performed by the Danmark-Ekspedition across the inland ice to Dronning Louises Land, the barometric levelling becomes quite uncertain, though this does not appear visibly through the barometric observations. In order to get the means of supporting the barometric observations under conditions of this kind, one ought for periods of several days to level at the same sharply defined points. If one succeeds in doing this, one will be able to form an idea of the uncertainty of the heights of the stations.

ad 3. Ill-defined sighting points are the most dangerous of the sources of error, because very often the result is a complete confusion of the points. But even if one only has two sights at such a point, and the levellings do not harmonize, it is, however, not always necessary to condemn the observation. In case the one sight is short and very nearly horizontal, it may perhaps be used, if, for instance, in the sketches one has sufficient support for marking off the point in the map. On the other hand it would of course be quite wrong to use a mean of the two values of the altitude.

ad 4. It has already been pointed out that the levelling becomes uncertain, when the distance exceeds 30 kilometres, but for that reason one ought of course not to omit levelling at greater distances; only one must fully realize that the uncertainty of the refraction nearly increases with the square of the distance, and so may become very large. The greatest distance at which levellings were made on the Danmark-Ekspedition was about 140 km.

Sometimes it is possible to conclude from certain meteorological conditions that on the day in question there exist more or less ab-

Table of results of levellings from various stations.
(See Pl. III: Northeast Greenland from 76°09' to 78° N. Latitude. Scale 1 : 500000).

Station	Altitude of station m	Point 2100, Dronning Louises Ld.		Point 670, Kap Bellevue		Point 1710, Dronning Louises Ld.		Point 1940, Dronning Louises Ld.		Point 1770, Dronning Louises Ld.		Point 1900, Dronning Louises Ld.		Point 800, North of Sælsøen		Point 890, West of Sonnerbræen		Point 700, Bistrups Bræ		Point 900, Bistrups Bræ		Point 970, Dronning Louises Ld.		Point 1000, Dronning Louises Ld.		Point 1390, Dronning Louises Ld.		Point 1970, Dronning Louises Ld.		Point 240, Nunatak		Point 1100, Dronning Louises Ld.		Point 1990, Dronning Louises Ld.		Point 650, Dronning Louises Ld.	
		Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km	Altitude m	Dist. km
W. & L. VII, inland ice ..	310	2215	84	672	19.0									887	27.5																						
W. & L. VIII, inland ice ..	300			701	6.1									824	41.9																						
K. X, inland ice.....	190					1745	65.0																														
K. XI, inland ice.....	330					1705	55.2	1947	68.5	1768	62.2																										
K. XII, inland ice.....	440					1660	43.5	1922	58.2	1729	51.3																										
K. XIII, inland ice.....	660					1698	30.0	1945	45	1758	36.2	1873	42.2																								
K. XIV, Ymers Nunatak..	870					1705	23.2			1779	30	1911	35.3																								
B. XXIV, Teufelkap	870	2039	126			1573	140																											1930	135.5		
B. XXV, SE of Brægerne	120																							979	55.5	1370	68.3	1973	88	227	34					599	46
B. XXVI, Brægerne	160	2130	74.5			1692	67.6	1922	74.8	1791	75.6					818	65	690	59.7	901	78	974	32.5	1124	44.5	1399	57	1934	76	249	20	1148	44.3	1991	73	651	29
B XXVIII, Hellefjord	440	2058	92			1596	80			1652	78					730	86	636	72.7	798	102	964	55	826	65			1913	95	228	41	957	63	1950	86		
B. XXIX, Spydodden .	170															778	90.6			1007	111																
Established value		2100		670		1710		1940		1770		1900		800		800		700		900		970		1000		1390		1970		240		1100		1990		650	

normal conditions of the terrestrial refraction. The anomalies arise from the fact that the ray of light must pass one or more "inversions" (for fuller particulars as to this, see chapt. I, Terrestrial Refraction). As outward signs of the existence of inversions of this kind we may mention the presence of foehn clouds and mirages (see illustration in Medd. om Grønl. XLII, Meteorol. Terminbeobachtungen am Danmarks Havn von Alfred Wegener pp. 308—309 and 252—293). The inversions do not, however, invariably disclose their presence in a visible manner, but may sometimes be recognized by the fact that the wind conditions are subject to change during the ascent of the mountain. That one may have calm at sea but a fresh breeze on the tops of the mountains, is an observation which is very often made. Under conditions of that kind one must be prepared for the levellings becoming uncertain, and, therefore, the observation journal ought to contain notes to guide us in this respect.

After this it will hardly surprise anyone that there are big deviations between the results of the levellings at the same point, and that the altitude of the various points is determined with a most unequal degree of certainty.

In order to prevent this fact from lessening the value of the indications of altitude on the maps, I have divided the figures of altitude into four groups, according to the following rules:

1. Whenever I had to look upon it as being out of the question that the altitude could be encumbered with an error of 10 metres, and where the uncertainty would thus only appear in the ones, I have expressed the altitudes by figures which do not end in 0. On Store Koldewey the highest point is thus given as 971 metres. Here one cannot rely on the figure 1, but only on the 7. This, of course, does not mean that the ones are quite uncertain; the uncertainty will only in very few cases exceed a couple of units.
2. Wherever I have had to look upon it as being out of the question that the altitude could be encumbered with an error of 100 metres, and where the uncertainty could thus only manifest itself in the tens, I have expressed the ones by 0 and the tens by a figure, which is not 0.
3. Wherever the uncertainty amounted to 50—200 metres, I have expressed both ones and tens by 0.

4. Wherever the uncertainty exceeded a couple of hundred metres I have condemned the levellings, and have not indicated the altitude in the map.

In many cases it does not occasion any inconvenience to form an estimate of the accuracy of the altitudes. This was, for instance, the case at the points levelled on both sides of the Annekssøen, where levellings were made at quite short distances and by means of a base measured on the lake. Here the errors in the altitudes of the points levelled could practically only proceed from the uncertainty of the altitude of the surface of the sea, which may amount to a few metres. In other places a considerable amount of work has been needed in order to form an estimate of the accuracy and at the same time to deduce the most probable values of mutually disagreeing single results. This was particularly difficult as far as Dronning Louises Land was concerned, because the distances here were, as a rule, so great, that for that reason alone one could not avoid a considerable uncertainty in the refraction. In order to be able to weigh the results of the levellings from the various stations against each other, it has here been necessary to make a table of these results. An extract from such a table is given above. In this manner one gets the means of estimating whether certain stations, on an average, give too high or too low values, (the stations K. XII, B. XXIV and B. XXVIII thus seem to give too low values), and in the same manner one may also get the impression that certain stations give particularly reliable results (f. inst. B. XXVI). This in its turn becomes of importance when establishing the final value of the altitude, in particular in those cases where there are only two levellings or even only a single levelling at a certain point.

That one ought not, in such circumstances as the ones shown in the table, to content oneself with the idea that the mean is the most probable value, is self-evident. After having compared the results from the single stations taken together, one must, as far as possible, argue the sources of error in the case of the single points. These arguments must be made with the working map and the observation journals before one.

Examples of arguments of this kind corresponding to points in the above table:

Point 2100. The working map shows that the position of the point is determined with an uncertainty of a couple of kilometres. As the distances at which the point has been levelled vary from between 74.5 and 126 kilometres, the uncertainty of the position of the point, already in the correction for refraction and curvature of the earth, gives an uncertainty of 20—60 metres. At stations W. & L. VII

the conditions were unfavourable (temp. ÷ 29°) B. XXIV and B. XXVIII everywhere seem to give too low values; on the other hand B. XXVI seems to give particularly reliable altitudes. The result of the research is that the altitude probably lies between 2100 and 2200 metres. Established value 2100.

Point 670. Both distances are here so small that the uncertainty in the refraction becomes of no importance. The working map shows that the two bearings intersect one another under a rather acute angle; the sketch shows that the sighting point has not been very clearly defined. The uncertainty of the position of the point in relation to the stations may be estimated at 1 to 2 kilometres in the direction of the sight. For station W. & L. VII $\cot z = 0.0178$; for W. & L. VIII $\cot z = 0.0650$. An error of one kilometre in the distances would thus, in the altitudes computed, give an error of about 18 and 65 metres respectively. Result: the value determined from Station W. & L. VII is the more reliable. The result of the investigation becomes: The tens, it is true, are uncertain, but ought to be given in the map; established value 670.

As far as this point is concerned the extreme consequence of the argument would suggest its removal nearly one kilometre in the direction of the stations. In this manner a practically complete agreement between the altitudes computed would be obtained, and it would be possible to fix the final value at 650 metres. Here where beyond the levellings there are no other circumstances to suggest that the position of the point is wrong, I have not considered myself justified in moving it.

Point 1710. The sighting point extremely well-defined. The working map shows that the point is determined with great certainty. The levellings from K. XII, B. XXIV and B. XXVIII which give too low values, ought here to be condemned. Of the five remaining levellings the four give values between 1692 and 1705 metres; the fifth levelling, taken at a distance of 65 kilometres, gives a value of 1745 metres. The two most reliable levellings at a distance of 23.2 and 30.0 kilometres give 1698 and 1705 metres. The most natural proceeding would be to put the altitude at 1700 metres; but according to the system followed, this would suggest that the hundreds are not quite reliable, which would be absurd. Established value 1710[1]).

[1]) In itself it is not a pleasant thought to put the figure of altitude 1710 on the map, while considering 1700 a more probable value. The drawback is, however, not essential, compared with the evident advantages of the system.

One might avoid the difficulty by expressing the altitudes in hectometres and adding a number of decimals, corresponding to the certainty with which the altitude was determined. In the case in point we might then have put the

In the case of the other points similar syllogisms have been set up. The examples given, however, ought to be sufficient to show and justify the manner of proceeding used.

(As to the uncertainty of certain figures of altitude, which in the map stand on the border line between inland ice and land, see the following chapter).

Notes to the geographical maps.

The result of the geographical survey is represented in the three sheets: Nordøst-Grønland, Nordlige Blad, Maalestok 1 : 1000000 (Pl. IV), Nordøst-Grønland, Sydlige Blad, Maalestok 1 : 1000000 (Pl. V), as well as the somewhat more detailed Nordøst-Grønland fra 76° 09′ til 78° Nordlig Bredde, Maalestok 1 : 500000. The symbols used are intelligible, either directly or by means of the explanation of symbols to be found on the maps themselves. For those who might wish to penetrate deeper into the knowledge of the maps, a few supplementary remarks will, however, be necessary.

Scale. In the case of material so heterogeneous as that of the Danmark-Ekspedition it was impossible to fix the ratio of the scale, simply by taking into consideration the accuracy of the measuring. The consideration that certain details which might be of interest should not be too indistinct in the maps became, under these circumstances, our reason for adopting the scale of 1 : 1000000. In the immediate surroundings of Danmarks Havn, which was the object of the personal and frequently recurring researches of the scientists, a demand quite naturally arose as to the representation of a great number of details in the map. Further, such a great number of names sprang up in this locality that if only to find room for these it became necessary to make a special geographical map on a larger scale (1 : 500000).

The projection for the two sheets in 1 : 1000000, is the conform conical one. The 79th parallel is the developing parallel of both sheets.

The somewhat detailed computation of the geographical network I shall here leave out of the question altogether. On the other hand a remark as to the normal scale affixed to the sheets of the map may not be out of place.

If we put the ratio of the scale at the developing parallel (79°)

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altitude at 17.0. This principle would, however, be subject to the serious drawback that the majority of people would not get any direct impression of the altitude.

= the unity, the scale at the north and south frame of the map becomes $1 + \frac{152}{10^6} \cdot \left(\frac{9}{2}\right)^2$. The mean value between the unity and the last-mentioned ratio is chosen as the normal scale; it will fit in perfectly on the parallels 75°50′ and 82°10′.

The greatest error in the use of the normal scale appears in measurings in east—west along the parallel 79° (ratio of the scale $< 1 : 10^6$) and the parallels $74^1/_2°$ and $83^1/_2°$ (ratio of the scale $> 1 : 10^6$). The error may here amount to 0.001639 of the measurings in question. In the case of measurings over the whole width of the map this error will amount to 0.7 mm, which error is of no practical importance in a map of the kind which we are here dealing with.

The two sheets, scale 1 : 1000000, are drawn in such a manner that they may be pasted together so as to form one map, which comprises the whole distance travelled by the Danmark-Ekspedition. The pasting line lies nearly on 78°45′; it is laid down on both sheets by means of a fine dotted line in the east and west frames.

The map 1 : 500000 is drawn in the cylindrical projection of Mercator. The very variable ratio of the scale in this projection has necessitated in the map the delineation of a varying scale, the use of which will, however, be understood without further explanation.

A glance at the full map of the distances travelled by the Danmark-Ekspedition shows how extremely lucky it was, from a geographical point of view, that the expedition came to winter in Danmarks Havn (76°46′). In this manner we came to occupy a central position in those parts which required the greatest amount of cartographical work — the stretch from Bessels Fjord to Lamberts Land — where many winding small fjords and the abundance of rocky islands made it particularly difficult to get a general view and systematic arrangement of the cartographic labours.

North of Lamberts Land the coast line is less complicated, so that it was possible to provide a rather complete map by means of one colossal effort — a sledge expedition comprising 10 men, 10 sledges and 86 dogs, which as far as one of the sledge parties was concerned covered a period of from the end of March until the beginning of December 1907. The route which the individual sledge parties followed during the great sledge trips in 1907 is delineated on the two sheets, scale 1 : 1000000, and besides the observation stations are indicated by dates as well as by the initials, B (Bistrup), K (Koch), or T (G. Thostrup). As far as the observations of Hagen are concerned, it has not been possible to indicate the stations, because his observation journal from this journey has been lost. The very considerable part of "Nordøst-Grønland, Nordlige Blad", which

is due to Hagen (Danmarks Fjord, Hagens Fjord, Independence Fjord), was drawn by himself in map sketches made during the journey. When on May 28th 1907 I left the sledge party of Mylius-Erichsen at Kap Rigsdagen, Hagen showed me one of his journals. Here, on the spot itself, he had in the observation journal for every station made a little croquis, based upon a rough computation of the observations. Later on during the enforced summer stay in Danmarks Fjord he worked up these little map sketches into one map. Together with a few of Hagen's sketches this map[1]) was, after the death of Hagen and Mylius-Erichsen, brought to the depot on Lamberts Land by Jørgen Brønlund, and here I found the sketches by Brønlund's dead body, when in March 1908 I travelled north in order to obtain news of our three ill-fated comrades.

As Hagen lacked the means of a more accurate computation, in particular as far as the longitudes were concerned, his maps must necessarily suffer from certain drawbacks, which defect was, however, compensated for by a fortunate circumstance. When in May 1907 I went south from Kap Kjøbenhavn (Peary Land), I myself made the necessary observations for the determination of the position of Kap Rigsdagen, as well as of the direction to Kap Knud Rasmussen, and in this manner I was able to make a fairly accurate geographical network for Hagen's map.

On "Nordøst-Grønland, Sydlige Blad" two sledge routes are indicated: Bistrup's route in April—June 1908 to Bessels Fjord and the district round Teufelkap, and Mylius-Erichsen's route in November—December 1906 to Shannon Island and Pendulum Islands. The object of the latter voyage was not a cartographic one. It is remarkable in that it was performed by untrained men, in an unknown terrain and after the dark season had set in; it is characteristic of Mylius-Erichsen by the courage, recklessness and good luck with which he carried it through.

Two of the far-going sledge journeys of cartographic importance are indicated by the observation stations: J (Jarner, May 1908 to the interior of Ardencaple Inlet) and H (Hagen, October 1908 to the southern part of Jökelbugten).

On the map, scale 1 : 500000 the route is delineated for a series of journeys, the object being a cartographical one, that is:

Koch, August 1906 to Skærfjorden and Germania Land;
Trolle, October 1906 to Skærfjorden;
Hagen, October 1906 to the southern part of Jökelbugten;
Bistrup, 1906, 1907 and 1908 in and around Dove Bugt.

[1]) Published by Capt. G. Amdrup, Medd. om Grønl. XLI.

Finally the routes of Bertelsen in March 1908 and Koch in May 1908 have been delineated, in as far as they went across the inland ice to Dronning Louises Land.

On the map scale 1 : 500000 I have not been able to delineate the observation stations, because of their overwhelming number. As far as the two journeys on the inland ice are concerned, the stations are, however, discernible by means of the figures of altitudes, put in along the travelling routes.

I have mentioned, on several occasions, how heterogenous the cartographic material of the Danmark-Ekspedition is — and necessarily must be — as regards completeness and reliability. For the tracts in the neighbourhood of the stations and the travelling routes the material often contains such a number of details that it has not been possible to include them in the map, whereas in the regions situated at the greatest distance from the observation stations there are only few and often uncertain data. This circumstance, as self-evident as it is unavoidable, has caused considerable difficulties in the preparation of the map. When making maps of regions so difficult of access as Northeast Greenland, it is not justifiable to condemn all the less certain data, seeing that these, in the absence of others and better ones, are meanwhile of very considerable value; but on the other hand, the fact that in this manner the map becomes incomplete and unreliable, as far as certain tracts are concerned, ought not to weaken confidence in those parts of the map which have been prepared on the basis of more reliable and complete material. This consideration has, among other things, been a contributory factor towards my delineating the above-mentioned travelling routes and observation stations, because in that manner one gets a very simple means of estimating, where one may rely on the maps and where one ought to evince a greater or less degree of precaution as to the information contained in the map.

Below I shall give a few other points for the valuation of the reliability of the map. Here I must first of all insert a remark to the effect that the delineation of the travelling routes also has another object, that is to give an idea of who has performed the measurings, and where the persons in question have undertaken them.

The information given in this respect by the travelling routes must necessarily be incomplete, for which reason I shall, in this place, give some supplementary notes, dealing with this question.

Hagen took part as an assistant in the triangulation work of 1906, in the course of which he made surveys and drew a map of the area triangulated. The map was a good deal used during the stay of the expedition in Greenland, but only in the case of a few

stretches — mainly the east side of Store Koldewey — was it directly used for the drawing of the geographical maps, because later on a minute survey of the same parts was made by means of a plane table.

Koch surveyed the greater part of Annekssøen and considerable parts of Germania Land.

Lindhard and Wegener took charge of the cartographic work during Bertelsen's sledge trip in March 1908. Besides the terrain round the route indicated in the map, scale 1 : 500000, Lindhard and Wegener in the course of this journey mapped out the greater part of Sælsøen and a small section of Annekssøen.

Charles Poulsen made a croquis of the region west of Pustervig, as far as the interior of Hellefjord.

C. B. Thostrup, in the course of the sledge journey to Ile de France in April 1907, performed cartographic surveys on Ile de France and Germania Land.

G. Thostrup on several occasions made surveys in the terrain round Kap Peschel.

Nearly all of the members of the expedition have in a greater or lesser degree taken part in the survey work, and in various ways contributed to the compiling of the cartographic material. In particular Bertelsen must be mentioned, because he has taken part in the longest and most strenuous sledge expeditions, and because, through his excellent sketches, he has provided very good material for a figuration of the relief, which considering the circumstances is quite reliable.

The symbols used in the map will in the main be understood direct or by means of the explanation of signs. It will, however, be justifiable to set forth a few more particulars:

Contours are used not only to indicate the border line between land and water, but also to show the border line between land and inland ice, which line in nature often stands forth as sharply as a coast line. In the usual manner a fully drawn contour indicates the fact that the border line in question may be said to be plotted on the map, whereas a dotted line indicates a higher degree of uncertainty. In the places where the circumscribing contour between land and inland ice is left out altogether and is replaced by a colour transition in the map, it does not mean that we have no conception at all of the position of the border line, but simply that this conception is so uncertain that it has not been possible to express it in the drawing.

Where the coast line proper — the border line between land and water — is fully drawn, it may thus be considered as well determined.

This, however, does not hold good of the fully drawn border line between inland ice and land. The explanation of this is that the border line of the inland ice, which at a distance looks like an even snow plain, in reality forms very considerable waves, which may conceal low-lying ice-free country. In order to be able to rely altogether on a contour between inland ice and land, it is not sufficient that the latter may be said to be plotted; it must also practically speaking be travelled throughout the whole of its extent. The latter is the case with the western borderline of Germania Land, but on the other hand not with the eastern border line of Dronning Louises Land.

During the preparation of the map I have not devoted sufficient attention to the circumstances mentioned in this place. The contours of Dronning Louises Land ought, in any case, south of the 77th parallel to have been drawn exclusively in a dotted lines.

In the section on levellings (pp.360—365) an account has been rendered of the uncertainty with which the figures of altitude are encumbered.

For the points levelled and situated on the eastern border line of Dronning Louises Land another source of error is added on account of the waves of the ice, which source of error in a considerable degree increases the uncertainty. According to the above there is nothing to guarantee that it is really the border line between ice and land, which has been levelled; this line may lie considerably lower than the point measured at, and the figures of altitude in these cases may thus be and probably are too great.

How careful one ought to be, even in the case of an apparently rather certain cartographical material of a country enclosed in the inland ice, was borne in upon me during my stay on Dronning Louises Land in 1912. When I got as far as the small mountain which on the map is marked with the altitude 240, and which is situated on 76°42′ n. lat. and 23° w. of Grw. I saw that it was connected with Dronning Louises Land, both towards northwest and south, by quite a narrow and low-lying strip of land. In front of the mountain lay an extensive marginal lake, the altitude of which above the level of the sea was nearly 30 metres. Thus here there was in this part of the map rather a gross error in the contour of the land, and the levelled points situated in the border line of the map were evidently to be sought for on the mountain side about 60 metres above the real border line between land and ice.

The main principle followed for the figuration of the relief on the stretches surveyed by the expedition has been to represent relief, water courses &c. in the map, only in such cases where directions were found in the cartographical material. Hatchings for

mountains, signatures for water courses, local glaciers, local névés are consequently not only an expression of the fact that in the places in question there are mountains, water courses &c., but also a more or less reliable indication of shape and position[1]). As an example one may conclude from the map that the greater western part of Lamberts Land is bordered by a tall and steep mountain slope; on the other hand it would be wrong to conclude from the map that the interior of Lamberts Land is an even plateau. The fact that the terrain in this place is not represented in the map only shows that the material compiled does not give sufficient hold for a figuration.

From Haystack (75°43′) and in a southern direction the surveys of the Danmark-Ekspedition have been restricted to supplementing Payer's map in the interior of Ardencaple Inlet and in the bay northwest of Kuhn Ø. The remainder of the map of the Danmark-Ekspedition south of Haystack is a reproduction of Payer's map. Payer, however, as shown with sufficient clearness in the map, followed a somewhat different principle for the figuration of the terrain than the one I used. Thus Payer's map shows, on Hochstetters Forland, a great number of water courses. This means that here one may expect to come across many water courses; on the stretches surveyed by the Danmark-Expedition the water course signature on the other hand shows that for each of the signatures delineated on the map a water course is seen, the position of which is determined with a fair degree of certainty. It would thus be quite wrong if, for instance, one were to conclude from the map that on Hochstetters Forland there are comparatively greater quantities of running water than on Germania Land.

Ice and water. In the maps four topographically different formations of ice are represented, i. e. 1) Inland ice and local névés, 2) Icebergs, 3) Fjord ice and 4) Drift ice.

As regards the inland ice I have abandoned the usually accepted signature, the symbology of which seems to me to rest, in far too high a degree, on a wrong conception of the nature of the ice.

The circumstance that the inland ice of Northeast Greenland in several places extends so far across the sea that it must at last elude the firm ground and floats in the water, has the effect that at the transition between the floating ice and the ice resting on the bottom, enormous pressure ridges may occur, having a similar appearance to big pressure ridges in drift ice[2]). The hummocks in the inland ice,

[1]) This does not hold good of the part round the mouth of Hagens Fjord, where I have replaced the designation of Hagen, "undulated upland" with a signature.

[2]) For the further description with photographs of the natural conditions here mentioned, see pp. 7—19.

the source of so much trouble during the sledge journey, are indicated in the map (see Nordøst-Grønland, Nordlige Blad: in Jökelbugten at Nordre Depot, and several other places, also in the outer part of the Nioghalvfjerdsfjord).

The drift ice signature indicates the approximate limit of how far the drift ice can reach towards the shore. It will appear that the drift ice in no way everywhere can block the outer coast, which fact, among other things, plays a practical part on sledge trips.

On the map the fjord ice is indicated in the same way as open water. This is in itself unfortunate, and may give rise to misconception; but I have not been able to surmount this difficulty without making the map too complicated and the reproduction too expensive. Wherever we have come across fjord ice there must on some occasion or other have been open water. For that reason the map must, however, not lead one to suppose that late in the summer there should normally be open water in these places. This will not be the case, especially in the regions north of Germania Land. For further particulars as regards the drift ice and the fjord ice see chapt. VI "Features of the Geography of Northeast Greenland".

The names. The principle followed by the expedition in the settling of the names on the map was the simple one of respecting the explorers, traditional right of name-giving. The first consequence of this course must be to respect the names given by earlier explorers, in so far as they could be localized. This was the case with all the names chosen by the Germaniaexpedition; nevertheless Kap Bismarck has been removed to another locality than the one to which the Germaniaexpedition had attached the name. This happened in the following manner:

The Germaniaexpedition had placed the name Kap Bismarck at the extreme headland of a peninsula projecting in a southerly direction from what is now called Germania Land, and in such a manner that Kap Bismarck, according to the German map, came to be a kind of mark for making the northern entrance to Dove Bugt[1]). During a period of about thirty years this point was the northernmost, fairly surely determined locality on the coast of East Greenland. The name, therefore, became invested with a certain geographical interest, and quite naturally Kap Bismarck became the place which already before the Danmark-Ekspedition left home, according to the programme, had been selected as the wintering place of the expedition. When in August 1906 we entered Danmarks Havn, we passed a

[1]) See "Uebersichtskarte des nördlichen Theiles von Ostgrönland" in Die zweite deutsche Nordpolfahrt, Bd. I, p. 470.

peninsula projecting from Germania Land in a southern direction, and we took it for granted that the southern point of the latter must be the Kap Bismarck of the Germaniaexpedition. Also the Belgica-Expedition of 1905 had committed the same error, so that already before the return of the Danmark-Ekspedition the name had become historical as the designation of a locality different from the original Kap Bismarck.

The Germans passed across Stormbugten (Sturmbai) in April 1870, in other words at a period when the country was covered with snow; it must upon the whole have been difficult for them at any point of their sledge route to see the present Kap Bismarck, which only has a height of 63 m. A comparison between the German map and that of the Danmark-Ekspedition, scale 1 : 500000 by the way leaves no doubt that the Kap Bismarck of the Germaniaexpedition "das Kap welches die Dove-Bai östlich begrenzt"[1]) is the southernmost spur of the Harefjeld of the Danmark-Ekspedition. The geographical interest attached to the name Kap Bismarck, however, made it desirable that it should correspond to an important locality along the outer coast, as was also the conception of the Germaniaexpedition; I have, therefore, considered it more correct to let the name remain in the spot to which it had been moved by chance in the case of the Belgica-Expedition, as well as in that of the Danmark-Ekspedition, instead of fixing it to the original place about 12 km up the fjord.

In the year 1905 Duke Philippe of Orleans[2]) with his ship the "Belgica", the captain of which was the well-known polar explorer, A. de Gerlache, succeeded in reaching the coast of Greenland at Kap Bismarck. On July 27th the Duke went ashore on the small island, Maroussia (see Pl. II), south of Kap Bismarck. From here the "Belgica" sailed north along the outer coast of Germania Land as far as Ile de France, where the expedition once more set foot upon land. The "Belgica" now went further north along the solid ice, but turned back on July 31st at 78°16′ and sailed once more in a southerly direction. On August 4th the expedition once more set foot upon Ile de France, on August 5th on Kap Bismarck, and after that the "Belgica" went further south along the coast.

During the short stay in the waters north of Kap Bismarck the expedition seized the opportunity of making a croquis of those regions which were at that time totally unknown. But time was

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[1]) Die zweite deutsche Nordpolfahrt, Bd. I, p. 491.

[2]) Duc d'Orléans: Croisière Océanographique dans la Mer de Grønland 1905, Bruxelles 1907.

short, they had their oceanographic work to do, while the mapping conditions were in other respects very unfavourable, and A. DE GERLACHE himself criticizes the croquis in the following terms[1]):

"Notre reconnaissance de la côte orientale du Grønland au dela "du 77e parallèle dut s'effectuer trop rapidement et fut à la fois trop "contrariée par la brume et par de déroutants effets de mirage pour "que le croquis que nous en avons dressé réponde de façon satis- "faisante aux contours et au relief de cette partie de la terre grøn- "landaise. On ne devra y voir, par conséquent, qu'une simple "approximation.

"Nous avons représenté sur ce croquis ce que nous avons vu, "de très loin parfois, et non vraisemblablement tout ce qui existe en "réalité; il est donc probable qu'il sera profondément modifié par "l'Expédition danoise de M. MYLIUS ERICHSEN...

"...Les points remarquables dont nous avons fait des caps sont- "ils réellement des saillies de la côte elle-même ou marquent-ils "simplement les extrémités de parties élevées et d'arrière-plan, émer- "geant seules de notre horizon visuel; les blancs qui les séparent "sont-ils des fiords ou des vallées?...

"...Le cap Bourbon qui se présentait à nous sous les apparences "d'une île n'a pu être relevé que de la station A, et encore n'était-il "visible que du nid de pie. Le cap Bergendahl est également porté "sur la carte à l'aide d'un seul azimut et de la distance estimée au "jugé."

On this map, of which the Danmark-Ekspedition had received advance copies before starting from home, the Belgica-Expedition had placed a great many names. A very considerable number of these it was impossible to localize during our survey. Nor could it be avoided that two of the names immediately after our arrival in Greenland were referred to the wrong localities, which mistake I only realized quite a long time after the return of the Danmark-Ekspedition, when studying E. MÉRITE's excellent perspective sketches in the above-mentioned work by the Duke of Orleans, "Croisiére Océanographique dans la Mer de Grønland". The mistake, however, could not very well be rectified, as both of the names, Kap Marie Valdemar and Rosio Ø (Ilot del Rosio), had played a considerable part as far as the Danmark-Ekspedition was concerned, and had been used many times in diaries, journals, on labels &c.

[1]) Duc d'Orléans: Croisière Océanographique dans la Mer de Grønland 1905. Bruxelles 1907.

As regards a number of the French names it has not been possible to place them without some degree of arbitrariness, and besides it is not excluded that I may have committed rather serious mistakes in the placing on the map of several of these French names. I have, therefore, considered it most correct to illustrate the facts in the accompanying map sketch.

To the map sketch (Fig. 57) I shall further attach the following remarks:

The name Terre du Duc d'Orleans I have, at the suggestion of A. de Gerlache, moved to the continent inside Jökelbugten.

The name Pic de Gerlache I have not been able to localize. As this name in particular seemed to me one which should not be missing from the map, I have placed it on the continent at a peak about 900 metres high, which is visible from the pack ice.

The name Iles Françaises I have moved to the northernmost group of islands, which it is possible for the Belgica-Expedition to have seen.

The traditional right of name-giving of the explorer was by the Danmark-Ekspedition interpreted in the following manner, that each of the members of the expedition, as a matter of principle, was invested with this right, and consequently could suggest names. On the maps there may consequently, in less prominent localities, appear a few names which are only to be considered as a compliment on the part of the namers to relations or friends, who have nothing to do with the expedition. This right of suggesting names was, however, used in a very moderate and discreet manner. From a cursory examination and comparison with Chapter II in G. Amdrup's Report on the Danmark-Ekspedition (Meddelelser om Grønland XLI) it will appear that most of the names, especially those of more prominent localities, are of quite an official character. Of special names I will in this connection only mention the following:

Germania Land. This name was given to the land by Mylius-Erichsen to commemorate the fact that the Germaniaexpedition had discovered it and been the first expedition to set foot on it. Besides this name is to be considered as a compliment to the German member of our expedition, Dr. Alfred Wegener.

Norske Øer (Norwegian islands). The name is to be considered as a compliment to the two Norwegian members of the expedition, Harald L. Hagerup and ice pilot Karl J. Ring.

Nioghalvfjerdsfjorden (the fjord of seventy-nine). The name was originally merely a temporary denomination of the glacier-filled fjord north of Lamberts Land. When later on Jørgen Brønlund

Fig. 57. East coast of Greenland between 77° and 79° N. Lat.
Black contours and black names from the map of the Belgica Expedition; red contours and names from the map of the Danmark-Ekspedition.
The underlined black names have passed into the map of the Danmark-Ekspedition without their position being altered.
The observation stations of the Belgica-Expedition are indicated by the letters A to F.

Axel F. Aumodt Kjøbenhavn.

used the name in the page of his diary[1]) where he speaks of the death of Mylius-Erichsen, Hagen and himself the name acquired a significance which made it necessary to keep it.

Lamberts Land and Edams Kulle (knoll) (see the map, scale 1 : 500000). The names originate from a Dutch map[2]) of 1718, on which there are the following notes on the east coast of Greenland,

at about 78½ n. lat. "t. Land van Lambert opgedaen 1670."
" — 77 — "t. Land van Edam opgedaen 1655."

Edams Kulle is, as seen from the sea, the most prominent part of Germania Land.

As regards the names on Hagen's sketches from the region round Danmarks Fjord and Independence Fjord and their somewhat altered position on the final map, I shall in the main refer to the remarks made by G. Amdrup in the oft-mentioned Report on the Danmark-Ekspedition, pp. 221—22.

To the remarks of Amdrup respecting the names I will only add the following supplementary details:

Peary Land: The name is taken from the atlas of Greenland in four sheets, published by "Kommissionen for Ledelsen af de geologiske og geografiske Undersøgelser i Grønland". According to this the name is to be understood as relating to that part of Greenland, which lies northwest of Independence Fjord, and thus understod it has got into the publications of the Danmark-Ekspedition. In contradistinction certain American maps understand by Peary Land the country south of the supposed Peary Channel (see, for instance, the map published by the Geographical Society of Philadelphia in Northward over the Great Ice" (London, 1898, vol. II).

Pearys Øer (Islands). By this name Hagen designates in his croquis (Medd. om Grønland XLI, Pl. IV) some small islets in Independence Fjord. The islets, or at least some of them, were discovered by Peary and shown in his map sketch in "Northward over the Great Ice". I could not but consider it improbable that Mylius-Erichsen should have intended to honour the famous American explorer by associating his name with such an insignificant locality, and I have consequently treated Hagen's designations, Pearys Øer, as an illustrative note made on the map. Hagen quite naturally was anxious to show on the croquis that he had obtained connection

[1]) Report on the Danmark-Expedition, p. 192, and Pl. X, Medd. om Grønl. XLI.
[2]) Ibid. Note p. 15.

with Peary's map. As far as the south side of Independence Fjord was concerned, he could do it by marking the names Kap Glacier and Academy Bræ (Glacier). For the north side of the fjord this possibility did not exist, as Peary has given no name to this place. I therefore think that by the designation Pearys Øer Hagen wanted to say "the islands indicated by Peary". This being my view I have omitted the designation from the map.

Marie Sophie Bræen (see pp. 390—392).

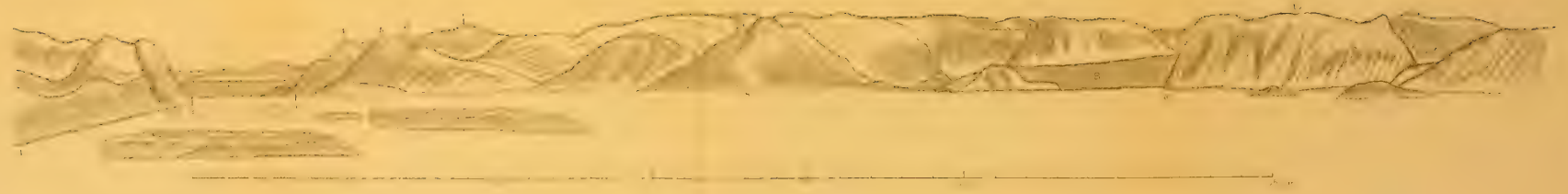

Fig. 58. Head of Independence Fjord sketched on 1. June 1907 by Haden.

CHAPTER IV.

Head of Independence Bay.

Sketched on 1. June 1907 by A. P. Høeg Hagen.

(Medd. om Grønland XLI, Pl. IX.)

After Mylius-Erichsen's sledge journey to the interior of Independence Fjord this locality was visited and mapped out during the voyage of Knud Rasmussen in 1912[1]). From the latter journey as well as from that of Mylius-Erichsen there are, however, no photographs from the interior of Independence Fjord. Hagen's perspective sketch is thus the only perspective representation from the fjord itself[2]), and as such it is of no mean interest to try to understand it.

Hagen's sketch (Fig. 58) is a panorama. In order to economize space it is originally delineated in two parts (see Medd. om Grønland XLI, Pl. IX).

In order to arrive at an understanding of the panorama we might begin by making an approximate estimate of the point from where it must be imagined to be seen. There is a priori an overwhelming probability that the sketch was made from Mylius-Erichsen's Cairn or from an observation station on the fjord about 3 km from the cairn. Pl. V in Medd. om Grønl. XLI shows that from these two places Hagen has laid down angles on his map. He has thus presumably here performed observations from two connected stations for the purpose of mapping out the interior of the fjord. It is besides a reasonable supposition — judging by Brønlund's diary as well as the report of Mylius-Erichsen of August 1907 (Medd. om Grønl. XLI, p. 472) — that the latter's sledge party must have been in this locality on June 1st, i. e. on the date of the panorama.

As Hagen has performed observations from Mylius-Erichsen's Cairn, one may take it for granted that as a link in the observations

[1]) Medd. om Grønl. LI.

[2]) In "Northward over the Great Ice", vol. I, p. 346, Peary publishes a photo taken from Navy Cliff of the region round Kap Glacier. On the other photos in Peary's book Independence Fjord is not to be found.

he has made perspective sketches, on which he numbered the bearings (as examples see Pl. VI in Medd. om Grønl. XLI and Pl. VI in Medd. om Grønl. XLVI). However, there are no numbers on Hagen's panorama of June 1st[1]). It must therefore, I suppose, be looked upon as a landscape sketch, meant for reproduction purposes, and the careful execution seems to point in the same direction (As far as I know, neither Mylius-Erichsen nor Hagen did any photographic work on this journey). Further, there is the possibility that the sketch has been meant to prove the surprising discovery that the "Peary Channel" did not exist.

The fact that there is no indication whatever of place or direction on the panorama places considerable difficulty in the way of understanding it.

Now supposing Hagen's standing place to be Mylius-Erichsen's Cairn, one may identify Point 2 (Fig. 58) as the point on Academy Kyst, which is touched by a sighting line from the cairn. According to Hagen's croquis (Pl. IV, Medd. om Grønl. XLI) this point lies at a distance of about 17 km from the cairn, and in the direction about N 123° W[2]). If this bearing is laid down on Freuchen's map of 1912 (Fig. 59) we find, however, that it does not touch the coast line, but falls considerably outside the latter. In other words, there is in this very place a divergence between the coast line of Hagen and Freuchen, which becomes of great importance in understanding the panorama sketch, in that on it rests the fact, whether or not Navy Cliff is visible from Mylius-Erichsen's Cairn. It therefore becomes necessary to subject the bearings shown by Hagen (Medd. om Grønl. XLI, Pl. V) to a closer investigation.

On Pl. V Hagen has shown two bearings from the cairn with the directions of about N 55° W and N 89° W. Further two other bearings have been sketched from the station out on the ice — on Freuchen's map (Fig. 59) this station is indicated by *b* — with an approximate direction N 121° W and N 130° W; the latter is presumably, according to Hagen's representation, to be a tangent to Academy Kyst. These four bearings, like the above-mentioned direction N 123° W, are laid down in Freuchen's map (Fig. 59) with fully drawn lines.

N 55° W. If this bearing is laid down in Hagen's Pl. IV (Medd. om Grønl. XLI) it practically impinges upon the eastern border of a glacier, which is designated as Marie Sophie Bræen. On Freuchen's map the bearing on the other hand crosses Heilprin Land 10°—20°

[1]) All the numbers and other designations have been added by the author.

[2]) That the frames of the map run north—south appears from the original, which is to be found at the Royal Library of Copenhagen.

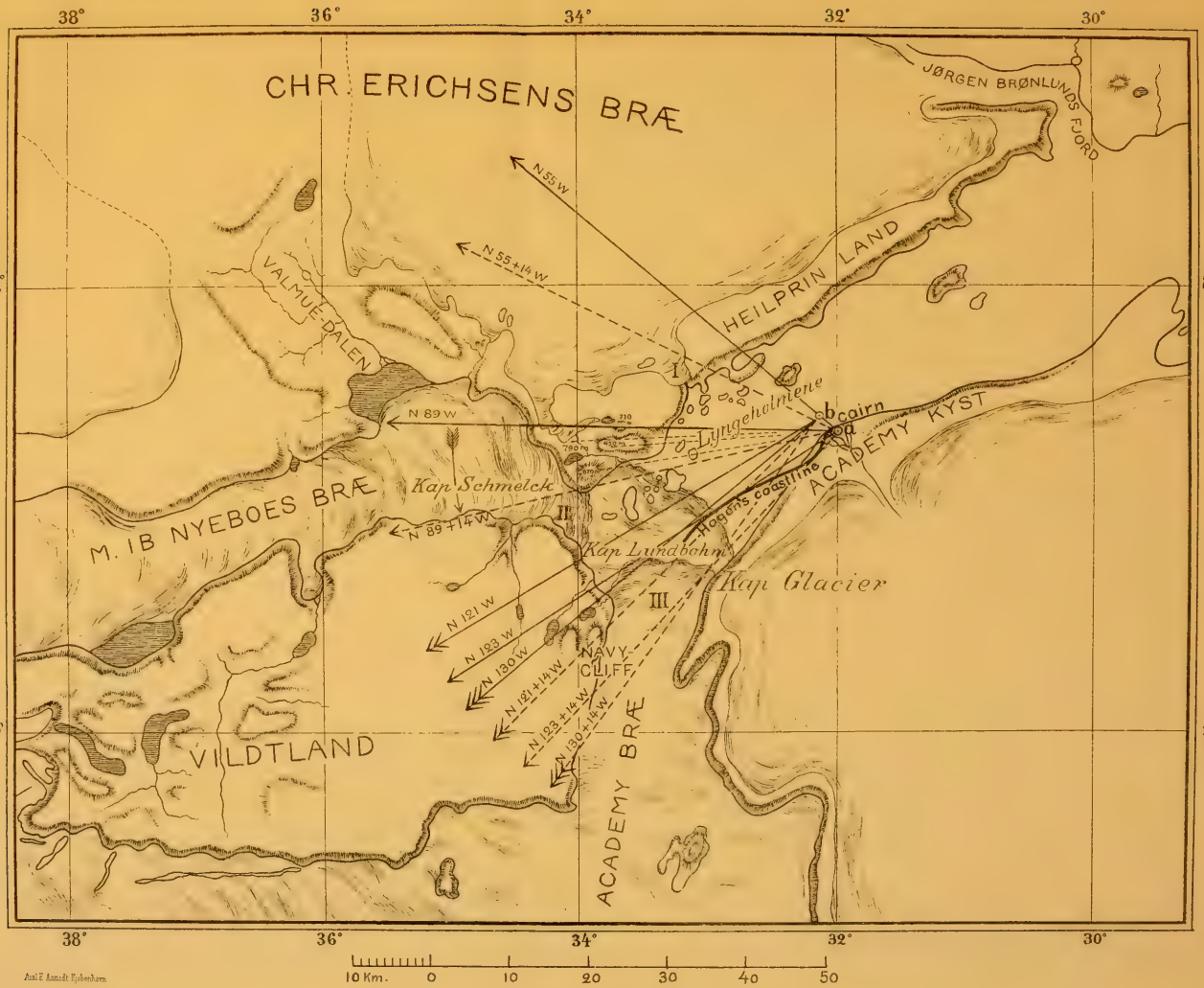

Fig. 59. Head of Independence Fjord and Surroundings from Freuchen's map.

east of Glacier I. This suggests an error in HAGEN's bearings of the same direction and magnitude as mentioned in the case of bearing N 123° W, and it further shows that Glacier I on FREUCHEN's map can be taken for Marie Sophie Bræen. That Glacier I does not extend all the way to the fjord, as shown on HAGEN's Pl. IV in the case of Marie Sophie Bræen, is a fact which will be touched upon later on.

N 89° W on FREUCHEN's map passes very nearly over a mountain, the altitude of which is given as 710 metres.

On the panorama HAGEN has by means of a short, vertical line marked off one of the mountain peaks (No. 7 on Fig. 58); this seems to indicate that this very peak has been of greater importance to him than the rest. One might suppose that the bearing N 89° W should actually indicate Peak No. 7 (Fig. 58).

This supposition is confirmed by the fact that both the positions and the altitudes of Peaks 4, 5, 6 and 7 (Fig. 58) fit in surprisingly well with the positions and altitudes of the peaks indicated by FREUCHEN, 670 m, 420 m, 790 m and 710 m. The fact that KNUD RASMUSSEN's expedition had to carry all their outfit across the mountainous terrain north of Kap Schmelck in the days 17.—30. June 1912, and in the course of this had to pass it many times, might explain the fact that FREUCHEN has had the opportunity of quite accurately determining the mutual position of the peaks.

In this manner the problem would then in the main be solved. Peak 4 (Fig. 58) would become FREUCHEN's Kap Schmelck; Glacier B (Fig. 58) would become Glacier I; Glacier A would become the outer part of the united glaciers II and III and the country above Glacier A must become Vildtland (the game country).

But the consequences of this would be:

1) Glacier I on FREUCHEN's map must be laid down at a point about 7 km too far west.

2) FREUCHEN's coast line from Mylius-Erichsen's Cairn towards southwest must be wrong, that of HAGEN correct. (For further particulars of this see below).

N 121° W on FREUCHEN's map nearly impinges on Kap Lundbohm. If Peak 4 (Fig. 58) was to be identical with Kap Schmelck, Kap Lundbohm should be discernible in the country behind Glacier A. This, it is true, is perhaps quite possible; the panorama, however, shows no point of such a prominent character that there seems to be any reason to measure at it.

N 130° W must, as mentioned above, be looked upon as a tangent to Academy Kyst. Here again we meet the difficulty that HAGEN's coast line deviates rather much from that of FREUCHEN. In order to make the bearing a tangent to the coast, we must presuppose:

1) either that the bearing is encumbered with an error of about 15 degrees, the consequence of which would be that Hagen's coast line from the cairn should fall about 15 degrees more towards south; or

2) that Freuchen's coast line is encumbered by a corresponding error in the opposite direction.

When weighing these two possibilities against each other it must be taken into consideration that Freuchen's observations must be supposed to be performed from highly situated mountain stations in the neighbourhood of Kap Schmelck, and during a stay of such long duration that he has been able to reject less favourable weather conditions. His later computations and the drawing of the map were performed under the most favourable conditions and with all technical means at his disposal. As to the conditions under which Hagen's observations were made, we hardly know anything at all. That time was limited is, however, a foregone conclusion, and the possibility is an obvious one that the observations were performed with an overcast sky, in other words, under conditions where it would be difficult or impossible to determine the azimuth with a reasonable degree of accuracy. As the coast stretch in question is situated west of Hagen's most westerly station, he has not been able to discover a possibly existing systematic error of the bearings by connection with observations from his other stations. As regards Hagen's computations we know that they were performed without the assistance of logarithms or other tables — though perhaps with the exception of a small azimuth table. His map sketches were made under very primitive conditions; the uncertain manner in which the bearings were laid down on Pl. V (Medd. om Grønl. XLI) speaks for itself.

In other words there is every probability that Freuchen's coast line is the correct one.

As mentioned above Hagen performed observations from two stations, *a* and *b*, situated at a distance of about 3 km from each other, and in such a manner that the line *ab* forms almost a right angle to the direction at Navy Cliff. This is hardly accidental, as in this manner Hagen was most favourably placed for determining his position in relation to Navy Cliff, where Peary had performed an astronomical observation of the position. The two stations, *a* and *b*, must therefore be supposed to be connected by distance and direction, but the consequence of this is that an error in the bearings from station *a* must appear with the same magnitude and direction, as far as the bearings from *b* are concerned. This consideration gives a natural explanation of the fact, why the bearing N 55° W falls east of Glacier I.

The supposition set forth on an earlier occasion that the bearing N 89° W has been directed towards Peak 710 on FREUCHEN's map must now be abandoned, and it becomes probable that instead of this it has been directed towards the front of Kap Schmelck. Supposing this to be the case the error of the bearings becomes about 14 degrees. If all the bearings are corrected in conformity with this we get:

N 55° + 14° W goes across the eastern border of Glacier I.

N 89° + 14° W becomes the tangent of the front of Kap Schmelck.

N 123° + 14° W becomes the tangent of Academy Kyst from Station *a*.

N 121° + 14° W may be supposed to be directed towards a cape on the east side of Vildtland. FREUCHEN's map does not show the existence of such a cape. However, PEARY in his above-mentioned sketch of 1892 indicated, southeast of Navy Cliff, a hollow towards Academy Bræ; I have shown this in Fig. 60 by means of a dotted line. On account of the vault of the glacier a cape may seem to appear nearly at *c* (Fig. 60), and towards this the bearing N 121° + 14° W might perhaps be imagined to be directed.

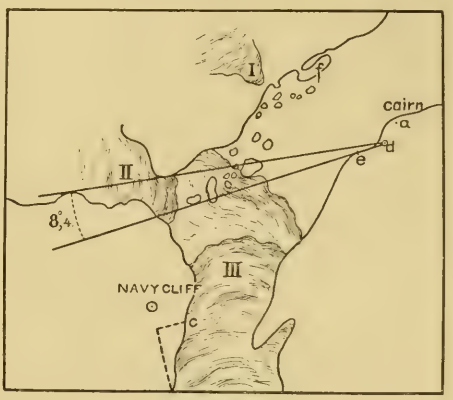

Fig. 60.

N 130° + 14° W tangent to Academy Kyst from Station *b*.

It has already been mentioned that Peaks 4, 5, 6 and 7 of the panorama in altitude and mutual position fit in surprisingly well with the Peaks 670, 420, 790 and 710 of FREUCHEN's map. According to this Peak 4 should be Kap Schmelck. This explanation is supported by the fact that Glacier I on FREUCHEN's map might in that case be supposed to correspond to Glacier B of the panorama. Against this consideration it may be urged, and with full justice, that in case Point 2 in the panorama is to be a point in Academy Kyst and Point 3 the front of Kap Schmelck, then the gap between 2 and 3 becomes far too small. Presuming that HAGEN's bearings are really encumbered with an error of about 14 degrees — which supposition seems extremely likely — the angle between the tangent to Academy-Kyst from the cairn and the direction at Kap Schmelck becomes nearly 41 degrees; if this should correspond with the interval 2—3, the whole panorama would exceed 360 degrees. The consequence of this must be:

1) either the panorama is not drawn from the cairn, or
2) Point 4 is not Kap Schmelck.

The first possibility cannot a priori be rejected. As one may take it for granted that the panorama does not form part of the cartographic material of the station, one might imagine it to be delineated from a position near the coast line southwest of the cairn. In this manner an otherwise immaterial projection of the coast near the standing place (the Point 2 of the panorama) might be supposed to cover the greater part of Vildtland, so that only the part which appears above Glacier A became visible.[1])

In the panorama Hagen has delineated two of the characteristic "sikosak" ice-blocks; their surfaces may, according to Freuchen, be supposed to lie 7 metres above that of the fjord ice.[2]) Measuring by the altitude of the two "sikosak" blocks Hagen's height of vision becomes nearly 30 metres and 24 metres above the fjord ice. The mean of the two determinations gives the height of vision as about 27 metres. Freuchen states that the "sikosak" blocks in the interior of the fjord become more and more closely packed. The result of this must be that the surface of the fjord which Hagen sees, already at a distance of a few kilometres from his standing place, comes to correspond to the surface ot the "sikosak" blocks and not to the fjord ice proper. Leaving out of the question the foreground of the panorama (Point 1), for which the height of vision must be put at 27 metres, one may thus reckon with a height of vision of about 20 m. According to this the "sikosak" horizon may be estimated at about $4\sqrt{20\text{ km}}$ = about 18 km. The dip of the apparent horizon becomes about 7'.7.

The apparent horizon in Hagen's panorama has in the main a course as shown in Fig. 61. From this it appears that the greater part of the coast line falls below the horizon; only the stretch 1—2, as well as a few small skerries quite towards the right, can with any certainty be said to lie nearer to the standing place than the apparent horizon, in other words, presumably within a distance of about 18 km.

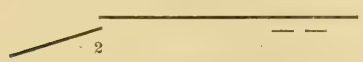

Fig. 61.

[1]) In the subsequent examination of the panorama I take it for granted that Hagen, while drawing it, had all the time faced that part of the landscape which at the present moment he was engaged in delineating, i. e. the panorama may be imagined to be drawn on the surface of a cylinder which later on has become unfolded. This presumption, however, will hardly be of any practical use, as far as the result of the examination is concerned, but only for the interjacent computation.

[2]) Medd. om Grønland LI, pp. 357 and 361.

Starting from the supposition that Peak 4 is identical with Kap Schmelck one may make an estimate of the distance from HAGEN's standing place to Point 2. When making drawings of the kind we are here dealing with experience, however, shows that amateurs considerably exaggerate the vertical measures in proportion to horizontal ones. It will, therefore, be necessary first of all to form an idea of the vertical measures of the angles.

If Peak 4 is to be identical with Kap Schmelck, the altitude may, according to FREUCHEN's map, be put at 670 m, whereas Peak 7 gets the altitude 710. The distances to these two peaks from the cairn are 32 km and 27 km respectively. The angular altitude of the peak, v, may now be computed from

$$H \div H_0 = D \tan v + \frac{1 \div k}{2\,R} D^2$$

where H is the altitude of the peak, H_0 HAGEN's height of vision, D the distance, k the co-efficient of refraction[1]) and R the radius of the curvature of the earth. From this we once more get the altitude above the apparent horizon by adding 7'.7 to v. In this manner the altitudes above the apparent horizon of Peaks 4 and 7 become 70' and 89' respectively. In the panorama the corresponding altitudes are 18 mm and 22 mm. For the angle of depression at Point 2 we get in this manner two expressions:

$$7'.7 + \frac{2}{18} \times 70' = 15'.5 \text{ and } 7'.7 + \frac{2}{22}\, 89' = 15'.8.$$

The two values harmonize, as it will appear, so well that as far as the estimate is concerned, it is immaterial which of the two one uses. If the angle of depression is put at 15'.6 and the height of vision above the "sikosak" at 20 metres, the distance to Point 2 becomes nearly 4.5 km.

One might now lay down Point 2 in FREUCHEN's map under the presumption that HAGEN's standing place was at d (Fig. 60). The horizontal distance 2—3 in the panorama is 34 mm. To this should correspond an angular distance[2]) of $\frac{14}{56.6} \times 34 =$ about 8°.4. Point 2 will then be near e (Fig. 60), and the course of the coast line must be very nearly as shown in the figure. So the supposition of an error in HAGEN's bearings had to be abandoned.

[1]) For k we have here used the value 0.2; it is probably nearer 0.4. This, however, is of no importance in this place.

[2]) The horizontal distance between 3 and 7 is in the panorama 56.5 mm. To this corresponds, as seen from the cairn, an angular distance of about 14°.

The estimates given rest on a very uncertain foundation, and there will hardly be anything to prevent the distance of 4.5 km from being double or half the size. The computations performed, therefore, do not disprove the fact that Point 4 of the panorama may be Kap Schmelck. As a positive result it may on the other hand be stated that the distance at Point 1 of the panorama becomes nearly 15 km, which can only be brought to harmonize with the presumption followed, i. e. that Hagen's standing place is near the southern coast line of the fjord.

It must further be noted that in case Point 4 is to be identical with Kap Schmelck, Glacier B in the panorama must correspond to Freuchen's Glacier I. In the panorama the distance 3—9 is about 280 mm; to this should correspond an angular distance of about $\frac{14}{56.5} \times 280 =$ about 69°.3. On Freuchen's map the angular distance as seen from the cairn is about 34°, whereas if we suppose Point 9 of the panorama to be in reality situated in the direction N 55° W from the cairn, it becomes about 48°. This seems to me such a serious consequence of considering Point 4 as identical with Kap Schmelck that there is every reason to test other possibilities.

Such a possibility — and, I suppose, the only one left — is that Glacier B in the panorama is to correspond to Glacier II in Freuchen's map. Peak 7, which is especially marked in the panorama, must then be supposed to be Navy Cliff, Peak 8 becomes Kap Lundbohm and Peak 10 becomes Kap Schmelck.

As the first test of this possibility we will compare the linear measures 2—7, 7—8 and 8—9 of the panorama with the corresponding angular measures in the map. In this connection I consider Point 2 to be given by the bearing N 153° + 14° W. Navy Cliff, which in Freuchen's map is not indicated by any sharply defined point, I have constructed by means of Peary's co-ordinates: Lat. 81°37′.1, long. 34°05′ W.

	Linear measure	Angular measure	Centimeter per degree
2—7....	about 9 cm	about 10°	about 0.9
7—8....	about 9 cm	about 12°	about 0.8
8—9....	about 13 cm	about 11°.5	about 1.1.

The harmony is almost as good as might be expected. The discrepancies do not arouse serious doubt and may, moreover, simply be explained by the fact that Kap Lundbohm (Point 8) is not a sharply defined point, neither in the panorama nor on the map. If this point is left out of the comparison, we get:

	Linear measure	Angular measure	Centimeter per degree
7—9....	about 22 cm	about 23°.5	about 0.9

in which manner the harmony with the stretch 2—7 becomes complete. FREUCHEN's map shows a water course, which from a lake near Navy Cliff runs towards northeast into the fjord. The panorama has a corresponding valley. FREUCHEN on his map has indicated a valley debouching on the north side of Vildtland, about 10 km west of Kap Schmelck; a corresponding suggestion is found in the panorama.

The panorama shows a cape at Point 3. On FREUCHEN's map there is no corresponding projection on the east side of Vildtland. I have already mentioned that a "cape" of this kind may owe its existence to the fact that the vault of the glacier, as far as HAGEN is concerned, conceals the bottom of a valley on the east side of Vildtland. (The depression is indicated on Fig. 60 by means of a dotted line, according to PEARY's map sketch of 1892). On the other hand HAGEN's drawing of the upper contours of Academy Bræ becomes unintelligible when starting from the supposition that Point 3 is to be the foot of a "cape" high up in the glacier. That this point is to be situated high up in the glacier not only appears from FREUCHEN's map (the distance from the front of the glacier to Point *c* is here about 12 km) but also from PEARY's coinciding descriptions from 1892 and 1895 in "Northward over the Great Ice". If the extent of the glacier is to be as indicated by PEARY and FEUCHEN, the upper contour of the panorama must be elongated to the right, very nearly as indicated by myself by means of a dotted line in the panorama. HAGEN's delineation of Glacier A would, on the other hand, fit in very well with the conditions at Kap Schmelck. It must, however, not be forgotten that the distance from the cairn to Point *c* is nearly 40 km. At that distance one will, even with the best conditions of light, always be exposed to misinterpretations of the landscape. As HAGEN was a mere amateur in respect of landscape drawing, there is nothing disquieting in the supposition that the definite lines in the panorama round Point 3 are not the expression of a corresponding definite conception of the terrain.

As one of the unlimited number of possibilities I shall mention: If HAGEN has delineated his panorama in the evening and in sunshine, the part of Academy Bræ stretching as far as below the Peaks 4 and 5 is made to lie in the shadow, whereas the remainder may have been sunlit like the surface of the fjord, as far as the latter was visible. In these circumstances the contour of Peak 4 indicated by HAGEN might correspond partly with the contour of the mountain and partly with that of the shadow of the mountains on the glacier.

If Point 7 is to be identical with Navy Cliff, Point 10 must be Kap Schmelck. PEARY gives the altitude of Navy Cliff as 3800 feet, to which corresponds 1158 metres. The distance from Mylius-Erich-

sen's Cairn to Navy Cliff is about 43 km. The correction for refraction and curvature of the earth corresponding to 43 km may be put at 116 metres, Hagen's height of vision at 27 metres. The vertical angle of Navy Cliff above the horizon of the cairn thus becomes equal to

$$\frac{1158 \div (116 + 27)}{43000} \times 34°38' = \text{about } 81'.1$$

according to which the altitude above the apparent horizon becomes nearly $81'.1 + 7'.7 =$ about $88'.8$. In the panorama the corresponding linear measure is 22 mm. In the panorama Point 10 has an altitude of about 25 mm above the apparent horizon. This altitude is to be reduced by about 1 mm, as shown by the joining of the two parts of the panorama. In this manner the angular altitude of Point 10 above the apparent horizon becomes about $\frac{88'.8}{22} \times 24 =$ about $96'.8$ according to which the altitude above the horizon may be put at $96'.8 \div 7'.7 =$ about $89'$. This value gives in the case of Kap Schmelck the altitude 920 metres or about 250 metres higher than indicated on Freuchen's map. The discrepancy would correspond to an error of about 6 mm in Hagen's drawing. It is perhaps not probable that Hagen should commit such an error of drawing, nor is it necessary to presume this, Peary's altitude of Navy Cliff being harometrically determined after a very long journey across the inland ice, for which reason it must necessarily be rather uncertain.

As a last objection to the hypothesis in question I will add that the panorama farthest to the right shows two skerries which lie considerably nearer to the standing place than the apparent horizon. The distance to the nearest skerries in the direction of Kap Schmelck is according to Freuchen's map about 18 km; these skerries according to the presupposition made must be visible in the apparent horizon. This objection is not very important, among other things because one cannot presuppose Freuchen to have measured at all the skerries. However, it derives some importance from the fact that there would be no corresponding discrepancy between Freuchen's map and Hagen's drawing, if one dared to look upon Point 4 as identical with Kap Schmelck.

The two conceptions of Hagen's panorama which have been discussed above may be briefly indicated as

a) Peak 7 identical with Freuchen's Peak 710 about 10 km northeast of Kap Schmelck, and

b) Peak 7 identical with Navy Cliff.

The former of these possibilities resulted in several rather serious consequences i. e.

1) The linear horizontal measures in the panorama fit very badly in with the corresponding angular measures in FREUCHEN's map.

2) It is necessary to suppose a course of the coastline immediately west of the cairn of Mylius-Erichsen, almost as shown on Fig. 60, but neither HAGEN's nor FREUCHEN's map justifies a presumption of this kind.

3) FREUCHEN's map must be encumbered with greater errors than one is likely to suppose.

The other possibility, it is true, does not result in such a complete harmony between the panorama and FREUCHEN's map as could be desired; but it is possible to explain the discrepancies without straining the facts.

There are scarcely other possibilities than the two mentioned above, and one consequently has to be content with the latter, as the one containing the balance of evidence.

According to this we get:

The stretch 1—2	Academy Kyst.
The stretch 2—9	Vildtland.
Glacier A	Academy Bræ.
Peak 7	Navy Cliff.
Peak 8	Kap Lundbohm.
Glacier B	M. Ib Nyeboes Bræ.
Peak 10	Kap Schmelck.

From the above reflections it appears that HAGEN most probably, in the interior of Independence Fjord, made observations from two stations which were connected with each other by means of azimuth and distance, and situated in such a manner that by bearings from them he has been able: 1) to obtain a good connection with PEARY's most reliable point, Navy Cliff, 2) to determine the main features of the inner contours of the fjord, and 3) to determine the position and altitude of the more prominent mountains.

It might seem all the more strange that HAGEN has not sketched the map of the interior of Independence Fjord, the locality with which the considerable geographical discovery of the non-existence of the Peary Channel was associated. In Medd. om Grønland XLI, p. 474, AMDRUP has hinted at the possibility that the paper which HAGEN used for his drawing, did not permit of his delineating the interior of the fjord. This may have been a collateral cause. I am,

however, inclined to look for the principal cause in the fact that Hagen, who brought with him Peary's map sketch of 1892 and whose bearings in the interior of the fjord, as indicated, must be supposed to be subject to an error of about 14 degrees, has not been able to bring about the necessary harmony in the connection between his own and Peary's observations. He has, therefore, forced by circumstances, put off this part of the preparation of the maps, until he had at his disposal a more complete computation of his observations.

The Marie Sophie Bræ. At the extreme western edge of his croquis (Medd. om Grønl. XLI, Pl. IV) Hagen has delineated a glacier which from Heilprin Land seems to project out into Independence Fjord, and on the croquis he has called it Marie Sophie Bræen, after the wife of Mylius-Erichsen. Only the eastern part of the glacier, the direction of which from Mylius-Erichsen's Cairn is nearly N 55° W, is shown on the croquis; the remainder of the croquis falls outside the paper, and consequently one can know nothing of its dimensions. As Peary on his sketch map in "Northward over the Great Ice", vol. I, p. 353, has not indicated any glacier in this place, nor mentioned it in his description of the view from Navy Cliff, I could not but suppose that the Marie Sophie Bræ was a comparatively insignificant glacier. Consequently I delineated it in small dimensions on the map of the Danmark-Ekspedition (Medd. om Grønl. XLVI, Pl. IV); at the same time I moved it a little towards west, in order to obtain harmony between the coast contours of Peary and Hagen on the north side of "Peary Channel". That this transfer did not harmonize with the real facts of the case has been shown by Freuchen's subsequent observations.

According to Freuchen's map it might be a case of two glaciers being identical with the Marie Sophie Bræ, that is M. Ib Nyeboes Bræ and Glacier I. The position of the former, however, in relation to the cairn harmonizes very badly with Hagen's indication. The direction to the northern edge of this glacier at the foot of Kap Schmelck is about N 89° + 14° W. In case the Marie Sophie Bræ and M. Ib Nyeboes Bræ are to be considered identical, one must presuppose that there is an error in Hagen's bearings of about 14° + 34°, which in itself is very improbable and besides causes other very serious results.

There is still the other possibility that Glacier I and the Marie Sophie Bræ are identical. As already stated on p. 383 the position and the direction of Glacier I harmonize closely with the position and direction indicated by Hagen for the Marie Sophie Bræ. But

HAGEN shows us a glacier which projects out into the fjord, whereas Glacier I stops short of the water.

In Medd. om Grønl. LI, p. 361, FREUCHEN writes about Glacier I: "From Chr. Erichsen's Bræ a tongue of ice runs down towards the coast". The expression here used by FREUCHEN hints at the possibility of the glacier projecting through a valley so far down towards the coast that only an inconsiderable foreland is left between the coast line and the front of the glacier.

The distance from the cairn to the coast in front of Glacier I is according to FREUCHEN's map about 19 km. Consequently the "sikosak", under the presuppositions made, conceals the lowest lying part of the foreshore up to an altitude of about 7 metres.

In order to enable HAGFN to apprehend the existence of a foreland in front of the glacier, the visible part of the latter, in a favourable light, must have a vertical angular extent of at least 1 minute. To this corresponds over a distance of 19 to 20 km a level difference of 6 metres. In a less favourable light, as for instance haze or a light snow drift, and especially under the oft-recurring disturbances of the refraction (mirages) prevalent in calm weather immediately above the sea ice, a foreland many times as high as this one may be quite lost to view. There is, consequently, nothing repugnant to reason in the supposition that in front of Glacier I there may be an even rather considerable foreland, though HAGEN could not possibly see it.

The fact of the Marie Sophie Bræ being identical with Glacier I on FREUCHEN's map is further borne out by a peculiarity in the coast contour of Heilprin Land. On the already mentioned Pl. IV HAGEN has delineated a projection of the coast line immediately east of the Marie Sophie Bræ. East of Glacier I FREUCHEN has delineated a peninsula, *f* (Fig. 60), and in Medd. om Grønl. LI, p. 361, he gives the height of this as 200 metres. Seen from Mylius-Erichsen's Cairn this very peninsula must look like a projection of the coast line, such as indicated by HAGEN. The peculiar inner contour of the peninsula *f* on FREUCHEN's map HAGEN apparently has not been aware of, and this harmonizes well with the fact that also the details of the coast in front of Glacier I have escaped him.

According to the above the Marie Sophie Bræ must be supposed to be identical with Glacier I on FREUCHEN's map. In the first published map of these regions (the map of the Danmark-Ekspedition, Medd. om Grønl. XLVI, Pl. IV) the name must consequently in the main be considered correctly placed.

With absolute certainty the question as to what is to be understood by Marie Sophie Bræen can hardly be settled, and besides the

possibilities mentioned there are others which are improbable, though they cannot be condemned as illogical. It might thus be imagined that Hagen considered the "sikosak" as a continuous sheet of glacier ice, which on the north side of the fjord reached as far as Glacier I, and that by the names Marie Sophie Bræen and Academy Bræ he wished to designate the two glaciers, which fall into the interior of the fjord, and which he possibly considered as flowing together and in company running far out into the fjord. That the panorama offers no support for an interpretation of this kind, and that it does not harmonize with Hagen's contours at the Marie Sophie Bræ (Medd. om Grønland XLI, Pl. IV) had to be explained away.

The circumstance that, as shown by Freuchen's Glacier I, there is a glacier on Heilprin Land, which as regards position and direction harmonizes well with the part of the Marie Sophie Bræ shown by Hagen on Pl. IV (Medd. om Grønl. XLI) however makes it the most natural solution to rest content with the conception that Freuchen's Glacier I and the Marie Sophie Bræ are one and the same.

Editor's note: *As* Kommissionen for Ledelsen af de geologiske og geografiske Undersøgelser i Grønland *are of opinion that the probability is that the name "Marie Sophie Bræ" was originally applied to the great glacier at the bottom of Independence Fjord, and as in cases of doubt regard must first and foremost be paid to the first pioneer who has the merit of the discovery, they have decided that in future publications issued by them, the name* "Marie Sophie Bræ" *will be placed at the end of the glacier at the bottom of Independence Fjord, and that the name* "M. Ib Nyeboes Bræ" *will be used for that part of the glacier lying behind, which Mylius-Erichsen had presumably not seen.*

CHAPTER V.

The topographic Survey.

Mode of Execution.

The fact that the expedition made such a long stay in one place quite naturally called forth the wish to undertake topographic surveys. In the immediate vicinity of the wintering place and in a few other localities, where scientific researches were made, the details of the landscape must come to play a part for us. Here there also arose a great number of names which served to localize and make clear the observations made, which names, however, would only be of importance to the scientists themselves under the journalizing of their observations, but which could not so well be used in the subsequent preparation of the material, as long as there were no detailed maps of the localities in question. The fact that a closer acquaintance with the entrance past Kap Bismarck might possibly be of practical importance — which among other things led to TROLLE's undertaking a marine survey of the entrance — also became a decisive factor in the settling of the question as to the making of topographical surveys.

To be used in the topographical survey the expedition had borrowed from the Topographical Department of the General Staff, Copenhagen, two universal diopters, two plane tables with appurtenances and four stadia. A detailed description of these instruments and their use under normal conditions will be found for instance in H. O. RAVN: Lærebog i Opmaaling, 2. Del, København, 1911. The method here mentioned, which in all essentials is the one used in Denmark and Iceland, however, requires ample time, a large number of assistants and, as far as the topographers are concerned, a training extending over several years.

In the case of the Danmark-Ekspedition these requirements could of course not be complied with, and it therefore became necessary to modify the method in view of the special conditions. The most important alteration consisted in the fact that the measuring of the distance, generally performed by means of the stadium and the

distance threads of the telescope, in the case of the Danmark-Ekspedition was performed with a special distance measurer, the stereo-telemeter constructed and manufactured by Zeiss in Jena. In the course of the survey itself the stadia were not used, and so two rodmen per topographer could be dispensed with. The stadia, which as far as the plane table survey was concerned were only used in the verification of the universal diopters, were not at all brought into requisition in the field.

The Zeiss stereo-telemeter is a binocle, the stereoscopic effect of which is strengthened thereby that the objectives are placed within a distance of each other of 0.5 m. This half metre is the base of the distance measurer.[1]) By means of prisms the rays of light are refracted twice in their passage from the objectives to the oculars. In the two fields of the telescope the two stereoscopic images of a zigzag scale are inserted. When using the telescope one gets in this manner the impression that a scale flashes across the landscape. In order to measure the distance at a definite point, all that is required is to give the telescope such a direction that the scale is made to pass over this point, and then the direction is read off direct on the scale.

The divisions of the scale run from 200 to 5000 metres. On the Danmark-Ekspedition we have, with great certainty, been able to measure distances with the stereo-telemeter of up to 1000 metres, and even within 2000 metres the uncertainty of the measuring of the distance generally did not play any part. For distances exceeding 2000 metres we could only use the stereo-telemeter, when the conditions were very favourable. If the distance exceeded 2500 metres, we could not rely on the measuring, even in the most favourable conditions.

The use of the stereo-telemeter requires some practice; according to experiments made in the Danish Army it even seems as if there are people who cannot learn to use it at all. On the Danmark-Ekspedition, however, the training in the use of this instrument did not cause us any trouble worth speaking of.

As regards the exactitude of the measuring of distances the relief, as was to be expected, played a certain part. Projecting object points, such as large stones, rocky knolls, crests &c are easy measuring objects; on the other hand it might cause trouble to measure at less projecting points in more even planes.

As advantages of the stereo-telemeter I have mentioned that it

[1]) Zeiss has manufactured two other stereoscopic distance measurers, a small one to be used at quite short distances, and a large one, which requires to be placed on a tripod, for the measuring of distances of several kilometres.

does not require the use of stadia and rodmen. It further deserves to be mentioned that with stereo-telemeters one may measure distances at inaccessible points, in which manner one becomes to a certain extent independent of the accessibility of the terrain. To conclude it must be stated that with the stereo-telemeter the distance is measured extremely quickly and without any auxiliary tables, that the instrument is very easy to transport, and that in all circumstances it serves the same purposes as a very good binocular.

It is a slight drawback that no scale has been provided for distances under 200 metres. When undertaking topographic surveys, such as those of the Danmark-Ekspedition, on a scale of 1 : 25000, 1 : 50000 and 1 : 100000 this, however, does not play such a great part that for this reason it is necessary to make special preparations for the measuring of short distances. If one sees fit to determine the position of a point within 200 metres, one may, for instance, measure the distance by pacing or, if it be near 200 metres, estimate it by means of the stereo-telemeter.

The points plotted were levelled in the usual manner; the altitudes were computed and written on the map with Indian ink, after which the linear signatures (watercourses, small lakes, coast contours &c.) were delineated. The measuring from each station was concluded by a sketching of the relief by means of horizontal curves, the equidistance of which in scale 1 : 25000 was 5 metres, whereas in scale 1 : 50000 and 1 : 100000 it was ten metres. This sketching of the relief thus takes place in sight of the terrain; but the topographer does not leave the station, and his only reliable support is provided by the plotted points.

Compared with the circumstantiality and extreme accuracy with which the horizontal curves are delineated, for instance in the original minute survey map of the Danish General Staff, a sketching such as the one mentioned above is superficial and highly inaccurate, and it may be doubtful whether one is entitled to publish a map with curves of this kind, because in that way one lays oneself open to giving quite an erroneous idea of the accuracy with which the measuring is performed. The sketching of the terrain by means of equidistant curves is, however, the only way which leads to a fairly reliable result; the method, as it were, forces the topographer to let the pencil follow the terrain along all of its inequalities; it gives the topographer himself a direct and strong impression of the places where the uncertainty becomes too great, and enables him in the place itself to remedy this defect by determining the position and altitude of one or more new points of support for the drawing of the curves.

Notes to the Maps.

Danmarks Havn and Environs, scale 1 : 100000, Pl. II.

The triangulation in the autumn of 1906 was, as mentioned above, computed in the course of the winter of 1906—07. Immediately after my return from Peary Land towards the end of June, I stretched cardboard on the plane table, and on this I laid down the triangulation stations in scale 1 : 50000, intending to make a map of this scale of the entrance to Dove Bugt. I personally commenced the minute survey, and in the course of a comparatively short time I trained B. Thostrup, so that he was able to continue it independently, assisted alternately by Kofoed, Freuchen, Lindhard, G. Thostrup, Weinschenk, Poulsen and others.

The superficies of the map, 52×52 cm, nearly corresponded with an area of 680 km^2, of which, however, the greater part consisted of water. The surveys, which were carried out with great energy, made such progress during the favourable summer season, that I began to have hopes of being able to make a topographic map of an area four times the size of the original one. In this manner the map would in a considerable degree gain in interest. I therefore set up paper on the second plane table for a map of scale 1 : 100000, also 52×52 cm, and so that on all sides it should reach beyond the former. It is the result of these two plane table surveys which on Pl. II is published as one map, scale 1 : 100000. The soundings indicated in the map are, however, taken by Trolle independently of the land survey.

The part of the map measured in the course of the summer of 1907 — the stretch between Varderyggen, Harefjeldet, Maroussia and Syttenkilometernæsset — satisfies the demands made on the work, in the circumstances rather strict demands. Here there are for each square kilometre plotted from five to twenty points, and in such a terrain this was sufficient for the purposes of a map, which might really be said to give all the details of the landscape.

When in the autumn of 1907 it became evident that Mylius-Erichsen had perished, B. Thostrup had to undertake the considerable ethnographic work, which like the topographic survey demands that the most important field work is performed at the time of the year, when the snow hides as little as possible. It therefore became impossible for Thostrup to continue, according to the programme, the topographic survey already commenced. He would, however, not give up the survey, and so the work was continued until late in the autumn of 1907 and resumed in April 1908, in other words, at seasons when a great number of the details were hidden under the snow, when progress on land was very difficult, and the cold rendered the

plane table surveys extremely painful. The whole of the mountain area east and northeast of Varderyggen which was surveyed in the early summer of 1908 was, however, fairly satisfactorily mapped out, whereas the work in the southern district of Lille Koldewey, on Store Koldewey and the greater part of the terrain west of Varderyggen was very incomplete. Here the details of the coast contours are, it is true, reliable, but indications are lacking of a number of small lakes, water holes and small rivers, while also the delineation of the mountains, especially on the mountainous Store Koldewey and west of Stormelven, is extremely cursory and unreliable as compared to the rest of the map.

The cartographic material is thus rather heterogeneous. The original representation of the relief by equidistant horizontal curves could at the publication only be used for small portions of the map. I have, therefore, preferred not to use this manner of representation, but have published the whole map in a homogeneous manner, by means of hachures for the rendering of the relief.

Finally it must be noted that the geographical net is made on the basis of a provisional computation of the co-ordinates of the Observatory, the results of which were $\varphi = 76°46'18''.5$, $l = 18°43'.5$ w. of Grw. At the final computation of the co-ordinates the most probable values proved to be $\varphi = 76°46'14''.6$, $l = 18°42'.6$ w. of Grw.

Part of Winge's Coast, scale 1 : 25000, Meddelelser om Grønland XLV, No. I, Pl. VII.

At Stormkap, 10 km west of Danmarks Havn, MANNICHE had established an ornithological station, where he carried on systematic researches of the lives of birds. At MANNICHE's suggestion I, assisted by LINDHARD, surveyed the terrain belonging to the station. This cartographic task was of rather a peculiar character, in that the object was to represent in the map the topographic conditions which in a greater or lesser degree determine the lives of birds at the thawing season. As far as a large number of details are concerned, the map, which was made during the period 28/VI to 4/VII 1908 consequently shows a series of varying conditions in such a manner as they appeared during the survey, which conditions especially as regards wading birds and swimmers play a great part. The snow drifts are delineated in the size and shape which they had at the time; the large number of small melting water rivulets which only exist for a few weeks are included; the lakes, the ponds and the Stormelven are represented by open water; the fjord ice is designated by a signature, indicating the intricate network of water channels on the melting ice, which net in the main follows the

principal direction of the wind; tidal cracks and ridges along the shore are indicated quite faintly on the map.

Some species of birds chiefly live in a special kind of terrain which is characterized by certain peculiarities of the vegetation conditions of the soil.[1]) In the map these areas, which are thus also ornithologically different, are designated by various signatures. For the rest names and designations are so chosen that from the map direct one gets an impression of the abundance of species of birds which are to be found in this place. However, it is a matter of course that all the species have not been represented by the names; this, for instance, holds good of gull, ptarmigan, eiderduck and several others.

The map is a plane table survey. As the conditions were very unfavourable for the determination of the station by means of triangulation points, the survey was inaugurated by a cursory reconnoitring of the terrain, in the course of which the most important stations were marked off by means of small cairns. After that a base was measured on the fjord ice, between Terneskæret (the Sea-swallow Skerry) and the shore, and from the termini of the latter the nearest cairns were determined by means of graphic intersection of bearings. After that the other stations were determined, also by means of graphic intersection, according as the survey progressed. This method, which may give good results, when a smaller terrain has to be surveyed, would have been inapplicable in the case of the above-mentioned far more comprehensive survey, scale 1 : 50000 and 1 : 100000. For each square kilometre nearly ten points have been determined, which in this terrain was sufficient to enable us to sketch the relief, with considerable exactitude, by means of horizontal curves with an equidistance of 5 metres. At the publication I therefore in this place retained the curves.

Karte der Gnipahöhle (Map of the Gnipa Grotto), scale 1 : 4000 (Pl. I). A description of the Gnipa Grotto will be found in the present volume pp. 62 – 77. Here I will only mention the method of survey.

The survey was performed by myself, alternately assisted by Jarner, Wegener and others.

The position of this grotto in the terrain was determined by means of a trigonometric station pointing, in which manner we furthermore attained a reliable starting point for the levellings. The altitudes of the plotted points are in the map given in metres with one decimal.

[1]) For further particulars see Manniche's: The terrestrial mammals and birds of North-East Greenland, Medd. om Grønland XLV, pp. 7—9.

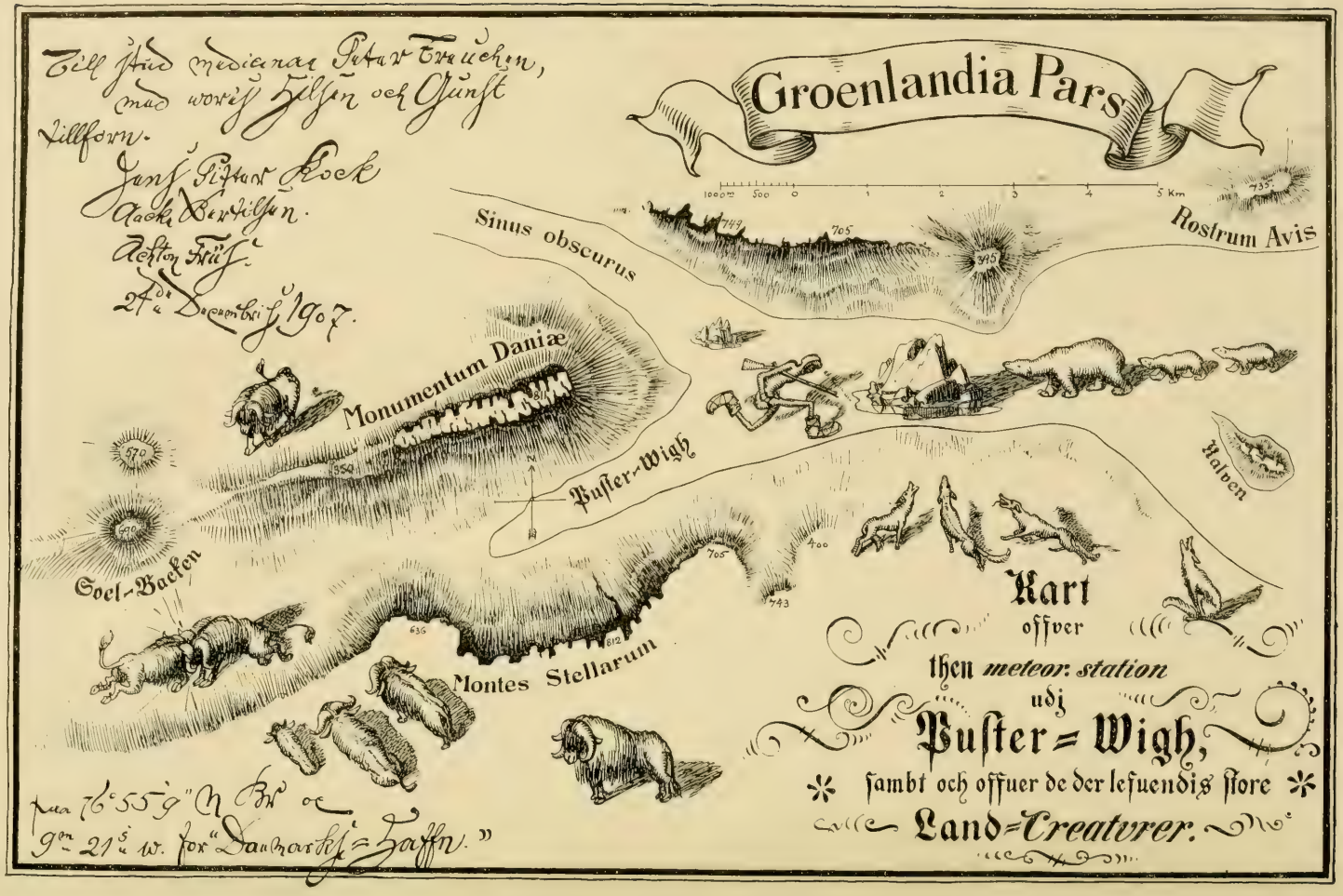

Fig. 62. Map sketch of Pustervig.

The framework of the survey formed a series of stations, the position of which was determined by means of a polygonal measuring with the small universal instrument and measuring tape. The polygon was conveyed from the above-mentioned starting point, determined by means of station pointing, through the grotto, which was 800 metres long, then through a hole in the upper part of the grotto and from there across the glacier back to the starting point. As the daylight could only penetrate into the grotto at the entrance, as well as in two places, where the roof had collapsed, the measuring of the greater part of the interior of the grotto could only be performed by means of lanterns and electric hand lamps.

The very shape of the grotto was determined by measuring abscisses and ordinates in a suitable number of transverse sections by means of stadia and measuring tape. The surface of the grotto glacier was measured by means of the small universal instrument, the reticule of which was fitted up for measuring distances in the usual manner by means of a stadium.

"Danmark"s Vinterkvarter (Winter quarters) 1906—08, scale 1 : 2000.

A description of the wintering place is given by G. Amdrup in Medd. om Grønl. XLI, pp. 72—77; in the same volume the map is published (Pl. III).

The survey, which was performed in October 1907 by myself, assisted by Wegener, took place by means of the universal instrument, measuring tape and stadium, in a similar manner as in the case of the grotto glacier.

The signatures of the gneiss particles exposed to daylight have unfortunately come out so badly in the reproduction, that it has become blurred and by no means clear.

Map sketch of Pustervig (Fig. 62).

The ice-free coast land of Northeast Greenland has in the main three landscape formations, the rounded hillocks (roches moutonnées), the plateau landscape and the alpine landscape. The topographic survey at the entrance to Dove Bugt was exclusively in the rounded hillocks, and this circumstance quite naturally made me wish also to represent the two other landscape formations in topographic maps. As far as the alpine landscape was concerned this was, however, impossible, as the distance between the wintering place and the nearest landscape of an alpine character was at least several days' march. On the other hand it was not a priori excluded that an opportunity might arise of making a topographic map of a smaller

area in the plateau landscape. An opportunity of this kind did, however, not offer itself.

In the autumn of 1907 a meteorological station was established at Pustervig, 62 km west of Danmarks Havn. On that occasion Wegener asked me to determine the altitude of the mountains round Pustervig, and as this locality belonged to the plateau landscape, I determined, on the same occasion, to try to make a small topographic map of the locality.

As the telescope of the universal diopter had a far too small play in the vertical plane, so that the instrument could not be used to advantage in the terrain in question, I made up my mind to perform the measuring with the universal instrument. The idea was to undertake a primitive base measuring and triangulation in the fjord and the valley of Pustervig, and simultaneously with the triangulation to determine by intersection of bearings the points necessary for a rough and ready map sketching. The work was, if possible, to be continued on the plateau itself.

Wegener and I performed the measuring experiment during the first half of November 1907. The altitude of the mountains was determined, but otherwise the attempt failed, the season being far too advanced. The sun had disappeared; the twilight only lasted for three hours, so that the daily working period in the field was short, to which must be added that the temperature was rather low, and that the snowdrift almost incessantly hid the terrain from us. After rather painful experiments, extending over a period of eight days, we gave in. The plateaus, which were 800 metres in height, we did not even succeed in climbing in the course of this experiment.

At that time I considered the material collected valueless and only used it as a little Christmas joke. For meteorological reasons Wegener wished me to compute the altitudes ot the mountains at the earliest possible moment. The material had consequently to be prepared at once, and I therefore at the same time sketched the contours of a small map of Pustervig, in order to give Wegener an impression of the situation of the levelled points. On the basis of this sketch the two artists of the expedition, Aage Bertelsen and Achton Friis, made a card, which as a humorous Christmas greeting was sent to Peter Freuchen at Pustervig on Christmas Eve, 1907.

Later on I found out that this sketch, though cartographically most incomplete, might, however, be of scientific interest. I have consequently published it in this place, with a few immaterial alterations, but otherwise as it was sent to Freuchen.

I feel deeply indepted to the late head of the Topographical Department of the General Staff, General Eiler Rasmussen, under whose supervision the three maps of the Gnipa grotto, the winter harbour of the "Danmark" and part of Winge's Coast were prepared, as well as to Mr. J. Petersen, engraver to the General Staff, who has re-drawn all the other maps. It is owing to the indefatigable patience and profound comprehension of the work displayed by these two gentlemen that it has become possible to illustrate in the maps in a pleasant and natural manner the characteristic features of the topography of Northeast Greenland.

CHAPTER VI.

Features of the Geography of Northeast Greenland.

Since the return of the Danmark-Ekspedition in 1908 Northeast Greenland has been visited by no less than three Danish expeditions, which more or less covered the same ground as the Danmark-Ekspedition. Through the work of these expeditions our knowledge of the geography of Northeast Greenland has not only been extended beyond the limits of the discoveries of the Danmark-Ekspedition, but as regards one important question, the problem of the Peary Channel, the erroneous ideas of the Danmark-Ekspedition have been corrected. Consequently it cannot be avoided that in the following description I am obliged now and then to draw my material from other and newer discoveries than those of the Danmark-Ekspedition. When in the following pages my sources are not expressly stated, the observations are due to the Danmark-Ekspedition.

Distribution of Land and Water. The Coast Line.

After the voyage of the Belgica in 1905 the usual supposition was that from the seventy-ninth parallel the coast line followed a northwesterly course with a direction towards Navy Cliff, which supposition, it is true, rested on a most uncertain foundation, but which to some extent was supported by the observations of Peary from Navy Cliff[1]), and which has been vaguely expressed in the then current maps. It was a great surprise to us that the coast line from Lamberts Land followed a course, which nearly formed a right angle to the direction towards Navy Cliff. The most easterly point of Greenland, Nordost-Rundingen (the Northeast Foreland), situated at about 81°24′ N. Lat., in that manner came to extend as far as the meridian 11°48′ w. of Grw., and the water distance between Greenland and Spitzbergen was narrowed down to about 450 km.

[1]) Robert E. Peary: Northward over the Great Ice, vol. I, p. 352.

Fig. 63. March. Snow-covered lowland near Danmarks Havn.

Fig. 64. March. Danmarks Havn.

Fig. 65. March. Thermometerfjeldet (Cairn XI) near Danmarks Havn.

Fig. 66. April. Nordre Depot. Jøkelbugten.

Fig. 67. April. Valley between Sælsøen and Annekssøen. Germania Land.

Fig. 68 April. Mallemukfjeldet, about 500 m high. Camping site. Sleeping bags and clothing drying in the sun.

Fig. 69. May. Stjernefjeldene, about 700 m high. Pustervig. Germania Land.

Fig. 70. May. Brystet (Cairn XX, 412 m) and Hvalsletten seen from Rypefjeldet, Germania Land. Note the strand lines.

Fig. 71. May. Cape in Smallefjord. Ardencaple Inlet.

Fig. 72. May. Head of Bredefjord. Ardencaple Inlet.

Fig. 73. June. Danmarks Havn.

Fig. 74. June. Breaking up of the rivulets. Vester Elven. Danmarks Havn.

Fig. 75. June. Breaking up of the rivulets. Vester Elven. Danmarks Havn.

Fig. 76. First half of July. Outlet of Vester Elven. Danmarks Havn.

Fig. 77. First half of July. Outlet of Vester Elven. Danmarks Havn. The water of the rivulet melting the ice of the harbour.

Fig. 78. July. Small lake near Danmarks Havn.

Fig. 79. July. The rivulets flood boggy tracts. Danmarks Havn.

Fig. 80. July. Outlet of Vester Elven. Danmarks Havn. Low tide.

Fig. 81. July. Water course of the Gnipa Cave glacier. Near Danmarks Havn.

Fig. 82. Latter half of July. Danmarks Havn.

Fig. 83. August. Drift ice in the Greenland Sea.

Fig. 84. August. Drift ice in the Greenland Sea.

Fig. 85. August. Drift ice in the Greenland Sea. The »landwater«.

Fig. 86. August. Mouth of the sound between Lille Koldewey and Store Koldewey.

Fig. 87. August. Danmarks Havn.

Fig. 88. August. Surroundings of Danmarks Havn seen from Cairn X.

Fig. 89. August. Basiskæret near Danmarks Havn.

Fig. 90. August. Lakelet near the Gnipa Cave. Germania Land.

Fig. 91. August. Lakelet near Danmarks Havn.

Fig. 92. August. Hvalsletten seen from Moskusoksefjeldene. In the background Sælsøen. Germania Land.

Fig. 93. September. Danmarks Havn before the first snow has fallen. New ice in the harbour.

Fig. 94. September. Northern part of Store Koldewey.
After the first snow has fallen.

Fig. 95. October. District near Danmarks Havn. After a snow storm.

It is a current layman's idea that Greenland and the sea surrounding it are covered with snow and ice, to such an extent that at times it is hardly possible to know whether one is on sea or on land. However erroneous this idea may be, generally speaking, it can, however, not be denied that it may be justified, as far as many localities of Northeast Greenland are concerned.

Not only in the summer, when the country is bare of snow, but also in the winter the coast line is usually very clearly defined; first and foremost because the snow, as a rule, does not accumulate in such quantities on the shore or on the ice along it, as to completely hide its foundation on longer stretches. That one finds oneself on

Fig. 96. Eastern coast of Hovgaards Ø. April. The beach almost concealed under the snow, whilst the coast line is rather clearly defined.

land appears as a rule, even on a level beach, from longer and shorter stretches bare of snow, or from the fact that rather big stones project through the snow. Besides, the surface of the drift ice is so uneven that the snow can hardly alter its character; only on the smooth bay ice it rather frequently occurs that the snow on long stretches conceals all outward traces of the foundation. It would, however, be quite conceivable that from a low foreshore one might pass across the coast line without noticing it, if it were not for the ice foot, the tidal pressure ridges and the tidal cracks. These phenomena, which for the greater part of the year are so characteristic of the coast line, are worthy of a more detailed description.

Tidal cracks and tidal pressure ridges arise in the manner that part of the sea ice forms on such low water along the coast that finally it rests firmly on the bottom, even at high water, whereas

the ice further out, where the water is deeper, floats in the sea. Thus the tide makes the floating sheet of ice rise and fall, whereas the ice foot[1]) along the coast is stationary. In this manner tidal cracks arise.

The freezing of the water in the tidal cracks, together with the inevitable horizontal shiftings in the floating sheet of ice, in its turn occasions tidal pressure ridges.

The formation of the ice foot takes place throughout the winter, as long as the ice increases in thickness. The factors which, generally speaking, determine the dimensions of the ice foot are the more or less evenly sloping character of the bottom, the altitude of the flood wave and the thickness of the ice, to which, however, must be added the effects of the tidal pressure ridges, as well as a few other factors, which in themselves have no connection with the formation of the ice foot (pressure ridges between drift ice and ice foot, accumulation of snow on the ice foot, sprinkling of sea spray when the wind blows on the shore) but which, when acting together with the ice foot, may materially increase its dimensions.

The difference between flood and tide only in exceptional cases exceeds 2 m[2]), and the limit of the thickness of one season ice may be put at a similar figure[3]). By a purely theoretical estimate we consequently arrive at the conclusion that in Northeast Greenland the ice foot should be formed on the very part of the shore situated between the high water mark and the low water mark, whereas the tidal cracks would be found at depths, which at low water are situated between 0 and about 2 metres. In forming this conclusion we have, however, among other things, paid no attention to the tidal pressure ridges.

Generally speaking the tidal cracks must open at the fall of the water and close up again at its rise. However, the freezing of the water in the cracks, the tumbling down of fragments of ice, the accumulation of snow and minor lateral shiftings prevent the cracks from ever closing up altogether. During the closing up there appear in this manner horizontal pressures round the tidal crack, by which

[1]) The designation "ice foot" is also used with quite a different meaning from the one given above, that is for the foot which often projects below the water from the edge of a floe or from an iceberg.

[2]) In Danmarks Havn the tide wave never reached 2 m, but on several occasions it came very near to it. In Germania Harbour, where the conditions correspond more closely with those of the outer coast, the flood wave only on one single occasion rose beyond 1.5 m.

[3]) On the Danmark-Ekspedition the thickness of the fjord ice has only in exceptional cases been measured at more than 2 m (Hydrographical observations from the Danmark-Ekspedition by Alf Trolle. Medd. om Grønl. XLI, pp. 395–399).

Fig. 97. Ice foot, tidal crack and tidal pressure ridges. Jøkelbugten. March.

the walls of the latter are broken to pieces, fall into the crack and so contribute to facilitate the freezing of the water in the crack and to increase the horizontal pressure. Room must necessarily be made for the new ice forming in the crack, and this can only be done by the ice lifting and placing itself like an irregular wall, the tidal pressure ridge, on both sides of the crack (see Fig. 97).

In this manner the originally floating ice along the outer wall of the crack is forced deeper down into the water and is made to stand on the bottom even at highest water, and so this part of the originally floating ice has now become part of the ice foot. The tidal crack under review ceases to act, and there arises, or rather has arisen long ago, a new tidal crack further out, where the same play and interplay is repeated. In this manner there may, in the course of the winter, arise several series of fairly parallel tidal cracks and tidal pressure ridges, and the ice foot may extend into a depth of water, which far exceeds the one corresponding with the maximum thickness of the floating ice.

The conditions here described in skeleton form are though more or less pronounced, quite a common occurrence in fjords and sounds. Only in the very few localities where the beach slopes so evenly and gradually that the ice cannot be broken by the flood wave, do tidal cracks and tidal pressure ridges entirely recede. This is for instance the case in the interior of Hellefjord and on the coast of Peary Land, north of Kap Eiler Rasmussen. In both of these places there is furthermore such a large accumulation of snow that it quite conceals the low beach, and so in springtime renders it all but impossible to determine the position of the coast line (see extract from diary and the footnote on p. 327). In the interior of Hellefjord this circumstance caused the coastline — most probably laid down by means of several snow-bare spots further inland — to be drawn too westerly, so that the innermost and last bight of the fjord became considerably greater than it should be, which error was discovered during my journey in the summer of 1912.

As in the fjords tidal cracks and tidal pressure ridges are often met with along the outer coast, even in some of those stretches where I have indicated on the map that the drift ice reaches in to the shore. The explanation of this is that the irregular, strongly pressed-up drift ice often has a deep draught. Consequently, along the shore and following the outer contour of the shallow water, there is often a narrow belt into which the ice cannot float, and in this belt fjord ice forms with tidal cracks and tidal pressure ridges. On the outer coast of Germania Land, where numberless small bays and creeks alternate with points and headlands, the drift ice is often met

with, pressed up on the shore round the points, whereas in the creeks there is fjord ice along the coast, which circumstance played no small part as regards the sledging of the expedition. Conditions similar to those at Germania Land are met with on the northeast coast of Peary Land, between Kap Clarence Wyckoff and Kap John Flagler.

In other parts of the outer coast the drift ice, however, on long stretches reaches so close inland that all ice outside the tidal crack must, at any rate now and then, be included in the drifting, and consequently only the ice foot remains. In such places the foreshore falls rather steeply towards the coast line, in which manner the ice foot, with the prevalent northwest winds, becomes situated within a lee belt, where the snow accumulates. At exceptionally high water the flood wave may still, for brief periods, send a little water across the ice foot; it then becomes absorbed by the accumulated snow, which in that manner is converted into ice. Now and then it also happens that the storm forces the drift ice away from the shore, so that for the time being an open coast water appears, from which the spray may be flung across the ice foot and contribute towards its growth; or it happens that the drift ice at high water is crushed on the ice foot and places itself along its outer part like a small pressure ridge, in which manner the conditions for the accumulation of snow and thus also for the growth of the ice foot become still more favourable.

Towards the end of the winter the ice foot, in such places, stands with a perpendicular wall of ice, which at low water is 2—3 metres high, and which thus projects well above the highest water.

An ice foot of this kind may be met with on the outer coast of Hovgaards Ø, Holms Land and part of Amdrups Land, as well as on the coast southeast of Nakkehoved.

Where the coast rises perpendicularly from the sea without a foreshore, the ice foot cannot form. Steep rocky walls facing the sea, without the slightest indication of a foreshore in front of them, is undoubtedly a rarely occurring phenomenon in Northeast Greenland, when rocky wall is taken in the ordinary sense of the word. With rocky walls we must, however, in this case class the steep walls formed by the inland ice through the breaking off of icebergs, and these steep walls are to be found in several places in Northeast Greenland, at Soranerbræen and Brede Bræ (Dove Bugt), probably also in a few places in the southern part of Jøkelbugten, on Hovgaards Ø and on two stretches of over 30 kilometres between Amdrups Land and Nordost-Rundingen.

On long stretches of Northeast Greenland, between the parallels

78° and 82°, the inland ice does not form icebergs, but spreads itself beyond the sea and gradually loses itself in the fjord ice. The deep layer of snow contributes towards making the transition between the inland ice and sea ice so imperceptible, that on long stretches it is often impossible to know whether one finds oneself on glacier ice or on sea ice. Very large portions of this continuous glacier ice float in the sea and therefore partake of the rise and fall of the tide. Consequently no tidal cracks and tidal pressure ridges are formed on the border line between the floating glacier ice and the sea ice; on the other hand the tidal phenomena often occur far in on this special kind of inland ice, that is, on the border line between that part which rests on the bottom and that which floats. These tidal cracks and tidal pressure ridges, often quite impressive and grand (see Fig. 4, p. 10, and Fig. 7, p. 13) may, however, correspond with water depths of more than 100 metres and have nothing to do with the coast line[1]). No visible coast line exists in this place; the border line between land and sea has disappeared; the very suggestion of a coast line has become uncertain, and in case one wishes to use the term, it must be done with an explanatory addition to the effect 1) that one imagines the inland ice to be non-existent, or 2) that one looks on the inland ice as forming part of the country. This latter consideration cannot be said to be without some logical foundation. Considering the unstable character of the inland ice, the former is, however, not only the more natural one, but the thus defined coast line is furthermore the one which is of greatest interest from a geological point of view.

It would in reality be of no small interest, if one could decide the approximate position of the coast line, in case the inland ice is taken to be non-existent, but a fairly reliable solution of this problem requires the knowledge of a series of circumstances concerning which we hardly know anything at all. In this respect we have, therefore, in the main to fall back upon an uncertain estimate by the map. Only as far as Germania Land is concerned, where we have several fixed points of support for the settling of the question as to the insularity of the country, is there any occasion to discuss the matter.

The west coast of Germania Land from Jøkelbugten to Dove Bugt, a stretch of 150 km, is blocked by the glacier ice from the two powerful ice streams, Kofoed-Hansens Bræ and Storstrømmen. We know that the eastern contour of Kofoed-Hansens Bræ indicates a real coast line, because northwest of the Anneksøen on the margin

[1]) A more detailed description is to be found in this volume in chaps. I, II and IV of "Die glaciologischen Beobachtungen der Danmark-Ekspedition von J. P. Koch und A. Wegener.

of the inland ice, 55 kilometres from the outlet of the glacier into the Jøkelbugten, we meet with the altitude 0 above the level of the sea. The altitudes along the ice margin between this point and the west end of the Sælsøen we do not know. The situation of the Sælsøen itself, in which the inland ice calves, is only 4 metres above the level of the sea; but south of the Sælsøen the border line between Storstrømmen and Germania Land rises to altitudes which have, it is true, not been measured, but which west of Mørkefjord we estimated at 300 to 400 metres. This supposition — which is, however, rather uncertain — was supported by a rough comparison with a barometrically measured altitude of 450 m of a peak, situated about 4 kilometres east of the ice margin.

The eastern border line of Dronning Louises Land between Kap Bellevue and the parallel 76°30′ hardly at any point reaches the height of 300 m above the level of the sea. Judging by the observations of the Danmark-Ekspedition only, there is nothing to prevent a supposition that the depression west of Germania Land, between Dove Bugt and Jøkelbugten, is a sound filled up by the inland ice, even though the remark quoted on the altitudes west of Mørkefjord might call forth doubt on this point.

The observations from the journey 1912—13[1]) support this theory of a sound west of Germania Land. In 1912 I found on the east coast of Dronning Louises Land at about 76°41′ a large marginal lake, the altitude of which above the level of the sea was nearly 30 m. The Storstrømmen calved in this lake, and icebergs, the altitude of which above the surface of the water was 10 to 15 metres, broke loose from the glacier and floated far out to sea. Even though the icebergs formed were of an irregular shape, it would, however, be unreasonable to suppose that the largest of these should not have a draught considerably deeper than 30 m. A safe conclusion from this is that the contour of the marginal lake at Dronning Louises Land very nearly coincides with the coastline.

In 1912—13 we succeeded in proving that the thickness of the ice on the face of the glacier southwest of Bræøerne was about

[1]) The Danish Expedition to Dronning Louises Land and across the inland ice of North Greenland, undertaken 1912—13 under the leadership of Capt. J. P. Koch. Of publications regarding this journey there is a popular account: J. P. Koch, Gennem den Hvide Ørken, København 1913. Further in "Meddelelser fra Dansk Geologisk Forening", vol. IV. København 1914, Koch has published "Foreløbig Beretning om de vigtigste glaciologiske Iagttagelser paa den danske Forskningsrejse tværs over Nordgrønland 1912—13" translated into German in Zeitschrift für Gletscherkunde, Bd. X, 1916.
In "Meddelelser om Grønland" will at a later date appear a full report of the journey, together with the collation of the scientific work of the expedition.

250 metres, and also that the depth of the fjord in this place must exceed 250 m[1]). The distance from Kap Bellevue to the above-mentioned part of the face of the glacier, southwest of Bræoerne, is nearly 48 kilometres. If the highest rate of motion in this part of Storstrømmen is put at 200 m a year, which estimate seems to be rather high, and if the ablation is put at half a metre a year, which on the other hand is presumably rather low, the thickness of the ice on the stretch between Kap Bellevue and Sæløen should be

$$250 + \frac{48000}{200} \times \frac{1}{2} = 370 \text{ m.}$$

As the surface of Storstrømmen between Kap Bellevue and Sælsøen does not reach much more than 300 m above the level of the sea, one should here meet with a "depth of the fjord" of 70 m or more.

In this place I shall not attempt to discuss the fully justified objections which can be raised against the above estimate, and which render the result uncertain, but simply remark that the result ought only to be looked upon as a factor pointing in the direction that the ice masses of Storstrømmen fill up a depression, the lowest part of which, south of Kap Bellevue—Sælsøen, is everywhere below sea level.

A series of observations thus go to show that Germania Land may be looked upon as an island, and so we arrive at the supposition that the coast line of the main land from Zachariae's Isstrøm may to all intents and purposes be supposed to follow the eastern contour of Hertugen af Orleans Land, and to continue from there in a southern direction along the east side of Dronning Louises Land, until as far as a little south of 76°30′. That the northern part of L. Bistrups Bræ conceals a fjord is known from the voyage of 1912—13; but the surface of L. Bistrups Bræ rises so abruptly towards the south that this fjord cannot be supposed to stretch very far south of 76°30′.

The Coast Sea.

In Northeast Greenland there is such a great external difference between the sea proper and the fjords, bays and sounds of the coast land that in the following I have elected to treat them separately.

The most conspicuous characteristic of the coast sea is the drift ice, whereas that of the fjords and bays is the comparatively smooth fjord ice. The border line between the drift ice and the solid ice is sharply defined, and even though it may vary a good deal, not only

[1]) See the above-mentioned treatise in "Meddelelser fra Dansk Geologisk Forening".

according to the seasons, but also from one year to another, it is, however, in the main so stable that I have considered it right to indicate it in the maps (Pl. IV and V). It will appear that the border line of the drift ice in the main follows the outer side of the extreme islands or of the projecting parts of the main land. Only between the 78. and 79. parallel does any difference exist. Here the border line of the drift ice passes from Ile de France to Norske Øer, far outside the extreme range of islands in Jøkelbugten, whereas in contrast to this it reaches as far as Hochstetters Forland in the gap between Store Koldewey and Shannon.

In these two places there is, however, every reason to expect

Fig. 98. Drift ice in the Greenland Sea. July.

great differences from one year to another. Information as regards the conditions north of Ile de France is only to be had from the years 1905 (the Belgica), 1907 and 1908, but for these three years the conditions seem to have been nearly as indicated in the map. As far as the gap between Store Koldewey and Shannon is concerned, the map shows the border line of the drift ice, as seen by us on the Danmark-Ekspedition in the years 1906, 1907 and 1908. The Germaniaexpedition hardly met with drift ice at Haystack during the sledge journey of 1870, as this would otherwise presumably have been mentioned in the report, and on the map[1]) against Kap Oswald Heer we find the word "Landeis", which must be interpreted as

[1]) Originalkarte von Ost Grønland zwischen 73°30′ and 76°00′ N. Br. von Julius Payer, Massstab 1 : 400000, (Zweite deutsche Nordpolarfahrt).

fjord ice. Nor have I in EJNAR MIKKELSEN's book[1]) been able to find anything seeming to indicate that the drift ice in the years 1909, 1910 and 1911 ran in as far as Hochstetters Forland.

The hydrographical conditions of the coast sea have been treated by TROLLE in Medd. om Grønl. XLI. A glance at the Pl. XII accompanying TROLLE's treatise shows that the conditions north of the parallel 78°16′ and west of the meridian 0 are completely unknown; among other things — which by the way is pointed out by TROLLE himself — the interesting problem of a possibly existing submarine ridge between Nordost-Rundingen and Spitzbergen is still an open one. The reason of our lack of knowledge as regards this part of the Greenland Sea is the quite natural one that it is extremely difficult to navigate in this very place on account of the density of the drift ice. The possibility of advancing with a ship in this part of the sea during a slack ice season is, however, not altogether excluded. In 1905, July 30th, the Belgica reached as far as 78°16′ (16°21′ w. of Grw.). In the ship's journal there is the following entry in this place: Au N: banquise compacte. Sur la lisière de la landice: traces de pressions. The Belgica was thus stopped by impassable ice on its journey north, but A. DE GERLACHE has told me privately that he believed in the possibility of being able to continue further north.

On July 24th 1908 the Danmark reached 78°04′ N. Lat. (14°10′ w. of Grw.). The ice did not prevent us from proceeding further in a northern direction; it was because our engine had become damaged that we were forced to turn round and try to go east, and here we were stopped by solid ice.

When in June 1907 I went south by sledge along the coast from Nakkehoved as far as Danmarks Havn, I found landwater, free of ice, between Nordost-Rundingen and Mallemukfjeldet. EJNAR MIKKELSEN, who travelled the same distance in the summer of 1910, likewise met with open water in this place.

Judging by the conditions in other parts of the Greenland Sea, it must be supposed that 1905 and 1908 were slack ice years, whereas 1907 was the opposite.

The above-mentioned four journeys, two by ship and two by sledge, are the only sources we possess for the estimating of the problem whether it is possible to go by ship along the coast of Greenland as far as Nordost-Rundingen. However, they seem to point towards the supposition that it ought to be possible.

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[1]) EJNAR MIKKELSEN: Tre Aar paa Grønlands Østkyst, København og Kristiania 1913.

Bays, Fjords and Sounds.

In Scoresby Sound and the Franz Joseph Fjords where the conditions are comparatively well-known, the fjord ice has not in a single case been known with certainty to remain stationary throughout the summer. Fjord ice, several years old, is not to be found here. As to the fjords outside Gael Hamkes Bai and round Ardencaple Inlet practically nothing is known in this respect, but there is every likelihood that also in this place perfectly open water would be met with during the latter part of the summer. As far as the Dove Bugt is concerned, observations have been made in the years 1906, 1907 and 1912. During these three years the ice sheet in the main remained on the bay, whereas the many small fjords and sounds presumably became free of ice. However, in the year 1912 the western and northern parts of the bay itself became free of ice about September 1st, in consequence of strong north-westerly winds. From Skærfjorden and further north one may venture to say that only in exceptional cases does the ice sheet disappear altogether. A single piece of driftwood found at Rekvedøen, however, seems to indicate that Skærfjorden can become free of ice. Driftwood has not been found in the fjords on the stretch between Ile de France and Nordost-Rundingen (on the other hand it is to be found, although sparingly, along the outer coast as well as frozen into the drift ice). However, the appearance of icebergs frozen into the fjord ice in Orleans Sund in the southwesterly part of Jokelbugten and in Hekla Sund shows that open water may form in certain places. From the report of Mylius Erichsen, dated Sept. 12th 1907 and brought home by Ejnar Mikkelsen[1]) we know that rather considerable quantities of driftwood appear in the interior of Danmarksfjord — a sure sign that this fjord may become free of ice. From the same account we further know that the interior of the Danmarkfjord in the year 1907 was open from shore to shore, while the ice presumably remained stationary farther out.

In one of his croquis Hagen[2]) indicates an iceberg at the mouth of Hagens Fjord, and from the journey of Knud Rasmussen in 1912 Freuchen[3]) states that in this place there are big disconnected floes of "sikosak" (inland ice formed on the sea). These observations show that Hagens Fjord may become open, but also — considering that the sikosak is perennial — that as a rule the fjord does not every year become free of ice throughout its full extent.

[1]) Medd. om Grønland, Bd. XLI, p. 472; Ejnar Mikkelsen: Tre Aar paa Grønlands Østkyst, p. 155.

[2]) Medd. om Grønland, Bd. XLI, pl. V.

[3]) "General observations as to natural conditions" by Peter Freuchen, Medd. om Grønl. LI, pp. 357–360.

Freuchen mentions the find of a single piece of driftwood in the interior of Independence Fjord in 1912, and further reports the appearance in this place of a great number of icebergs and sikosak floes frozen into the fjord ice. In this manner we get, as far as Independence Fjord is concerned, a similar impression of the ice conditions as we got in the case of Hagens Fjord.

In the following I will attempt to set forth and explain the causes of the peculiar ice conditions in the fjords and bays of Northeast Greenland, as well as to give a picture of the changes in the ice conditions according to the seasons.

The thicknesses of ice measured by Trolle towards the end of the winter of 1907—08 in Dove Bugt in the main fall between one and two metres[1]). The greatest thickness measured is of two and a half metres (Mörkefjord). In other places in Northeast Greenland one may, however, meet with solid ice which is very much thicker. The ship's journal of the Belgica for 1905 — published in the oft-mentioned "Croisière océanographique etc. — contains the following remark on July 30th: "La lisière de la landice a de 2 à 3 m de h' et présente des buttes", and on August 1st ($\varphi = 78°13'$, $l = 16°23'$): "La lisière de la landice a de 1 à 1.5 m de haut; à l'intérieur: plaine unie". To such heights in the edge of the solid ice must correspond very considerable thicknesses of ice.

In his above-mentioned account in Medd. om Grønl. LI Freuchen mentions that in the interior of Independence Fjord he met with fjord ice which was at least 5 m thick.

Besides the winter temperature and the prevailing currents the manner in which the snowfall is distributed over the fjord ice plays a very great part in the growth of the latter. The weight of the snow presses the ice down, so that the water comes over the top, where it soon freezes. In this manner the fjord ice can, where the conditions are favourable for the depositing of the snow, attain to a thickness far beyond that which it would otherwise have attained. Fjord ice formed in this manner constitutes the beginning of the sikosak (the sea glacier).

The manner in which the snowfall is distributed also in another way plays a part, as far as the fjord ice is concerned. In the autumn and early part of the winter a proper layer of snow forms a strong protection against the cold, and prevents the growth of the ice; and in a similar way a thick layer of snow may, during the early part of the summer, serve to protect against the influence of the sun and prevent the thawing of the ice. The varying ways in which the

[1]) Alf Trolle: Hydrographical Observations from the Danmark-Ekspedition. Medd. om Grønl. Bd. XLI, pp. 395—398.

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snowfall is distributed in different localities and in different years ought, therefore, to constitute one of the principal reasons why we may expect to meet with divergences in the fjord ice areas from one year to another.

At any time during the summer new ice may form on the water, but the duration of the new ice during the summer is a short one; it melts before the rays of the sun and in positive temperatures, or it is broken up on the first occasion by the fresh breeze. In the month of September the open water is covered by a more lasting sheet of ice; only wherever there is a current there are still openings in the ice, where belated aquatic birds assemble. In October the ice

Fig. 99. Wind-swept ice on a lake. March.

is so strong that one can travel on it with comparative safety. Now is the time for autumn journeys.

From November to March is the time for snow drifts. A wind velocity of 5 to 6 metres is sufficient to call forth a slight drift of snow; with greater wind velocities the lower stratum of air, up to an altitude of 10 to 15 metres, is filled with drifting snow. The wind velocities which determine the drifting of the snow, as it were, only occur when the wind is in the west and northwest. The transport of the snow therefore in the main takes place from land and out across the fjords and the sea, and they are undoubtedly very considerable quantities of snow which in this manner are deposited on the ice.

Out at sea the snow must be deposited fairly evenly over great stretches; this, on the other hand, is not the case on the fjords,

where the contour of the surrounding country plays a great part both as regards the direction and the velocity of the wind.

In Meteorologische Terminbeobachtungen am Danmarks Havn, Medd. om Grønl. XLI, pp. 341—345 WEGENER treats the subject of the natural law, according to which the snow is deposited. Roughly speaking the conditions are as follows: Wherever the wind blows out across a mountainous coast, the direction becomes a downward sloping one. When it meets the ice or the flat foreland, it is forced into a horizontal direction. In the place where the change of direction takes place, there is a condensation of the wind currents, which enables the air to convey larger quantities of drifting snow, than it

Fig. 100. Wind-swept ice along the coast. The ice knoll is formed above a rock by the tide in a similar manner as the ice foot.

contains beforehand. In this manner a wind-swept area is created along the coast. Only in calm weather can the snow be deposited in this place, but at the first drift it is carried out across the ice. Throughout the winter one often finds, in the wind-swept area a completely smooth belt of ice along the coast, which circumstance plays a great part, as far as the sledge journeys are concerned.

The depositing of snow begins, as a rule, at some distance from the shore, and increases up to a certain limit in the direction of the wind. The above-mentioned extremely heavy ice north of Ile de France is, among other things, a proof that this limit may be far out. Nearly all of the mouths of the fjords in Northeast Greenland are typical examples of depositing areas; uncommonly large deposits of snow have been encountered off the mouth of Ardencaple Inlet,

at the mouth of Nioghalvfjerdsfjorden and at the mouth of Frederick E. Hyde Fjord.

Thus in the main the quantity of snow increases on the ice from the coast outwards in the chief direction of the wind, up to a certain limit, but if one considers the individual cases, a number of apparent deviations from the general rule are to be encountered. Where the coast mountains are very steep, a lee belt forms immediately below them, and there the snow may accumulate in enormous drifts reaching far across the fjord (Mallemukfjeldet). Where the

Fig. 101. Accumulation of snow on the ice between Kap Buch and Kap Negri. Ardencaple Inlet. May.

foreshore is very broad and level (Herlufsholms Strand), the deposits of snow already begin far up on the foreshore, so that the coast line is quite hidden under its cover of snow.

On the whole the local topographical conditions play a great part as far as the direction and velocity of the wind go, and so also for the depositing of the snow. Among these factors only one is to be mentioned in this connection, that is the case where the snow drift meets with a considerable frontal obstacle. Then a lee belt forms to the weather side of the obstacle, where the air becomes comparatively still, and where consequently large quantities of snow may accumulate. An obstacle of this kind is made by the series of islands in Jøkelbugten, and here we also meet with the biggest accumulations of snow we have encountered on the ice. Presumably, Store Koldewey is of similar importance, as far as the deposits of snow go, but observations from this place are not forthcoming.

Throughout the winter and spring a partial re-crystallization of the deposited snow takes place. As the air contained in the snow must be saturated with ice vapour, the re-crystallization must take place, for the simple reason that the equilibrium pressure of vapour is different in the case of large and small crystals (the large ones "devour" the small), but apart from that the current of heat which from the warm ice must pass through the cold snow, serves to further the re-crystallization. The layer of snow nearest the ice evaporates and condenses once more in the higher lying strata. In this

Fig. 102. Lee belt at Mallemukfjældet, Holms Land. Accumulation of snow. Fog. June.

manner, simultaneously with the transformation of the snow into névés, extensive, low cavities appear, principally between the ice and the snow. When these cavities collapse, in consequence of the weight of the snow deposited above them, the air is pressed through the snow with a peculiar, sighing sound, which phenomenon has been described by the word "sigh" (a "sigh" in the snow, the snow "sighs").

In the month of April the fall of snow is particularly small. The time of the spring blizzards is gone; the snow hardly drifts, and so the deposits of snow have ceased to increase. As early as the month of May the sun becomes so powerful that the snow may begin to melt, but not till the month of June does the melting begin in real earnest. The melting water from the upper layer of snow is absorbed by the lower-lying ones, which are gradually transformed into a complete slush of snow and water. The upper layers, which

are still free of water, become loose, so that one sinks through them into the slush; only in the earliest morning hours, after the night cold has formed a more solid crust of ice, is one with tolerable ease able to get along on skis.

Sledge journeys out on the fjords are now extremely difficult. The greater part of the twenty-four hours it is hardly possibly to make progress, because the sledges stick, and the snow cannot bear the dogs. The camping site must be lined with skis, in order to prevent the tent from sinking into the slush, and from the sledges one must make a platform in front of the tent door, so as to be able at least to get out of the tent without immediately getting wet. Under such conditions it is generally preferable to try to get in under the land in the wind-swept area, or on the ice foot, even though it thus becomes nccessary to make a considerable detour.

Under the land one is often rid of the snow slush, but other, though minor inconveniences are encountered.

In the tidal cracks the snow has melted; at low water they form ditches, deep and difficult to pass, and at high water they are filled with water, so that along the coast a complete system of channels is developed, which on long stretches may be quite impassable.

Along the shore, where there has been no protecting layer of snow, the melting of the smooth ice is already so far advanced that in many places there is water on it; generally the depth of these lakes on the ice is, however, still quite trifling, and it does not prevent sledging.

Also on the ice foot the melting is in full progress. The old tidal cracks, which for months have lain dormant, now again become active, on account of the melting-off from below. The tide circulates in the latter, and so the ice foot becomes shrunken in breadth. The often rather considerable quantity of snow, which in the course of the winter has been deposited on the ice foot is now melting rapidly. Along the depressions in the rather uneven surface of the ice foot small lakes of melting water have formed; in other places the layer of snow has totally disappeared, and on the bare ice one sees the often quite considerable quantities of pebbles and gravel, which the winter storms have carried across it together with the drifting snow.

During the latter half of June the rivers break up and send a flood of water out across the ice. The water of the rivers, the temperature of which rises to several degrees above zero, greatly furthers the melting of the ice, and soon there is in front of every river mouth a smaller or larger lake with quite open water, which quickly spreads over larger areas. Particularly in the interiors of

the fjords, where the spring is farthest advanced, where the air is quite mild in the deep river valleys, and where a fairly large river as a rule sends very large quantities of water across the fjord, whilst innumerable tiny rivulets of melting water trickle over the beaches along the sides of the fjord — here in particular the melting of the ice is far advanced. The innermost parts of the fjords are already quite open. The wind which sweeps the valleys of the fjords in a longitudinal direction may produce small waves along the surface of the water, and the wear and tear of the waves now begins to make itself felt and helps to disintegrate the ice.

Fig. 103. Lakes forming on the ice of the harbour. First half of July.

We are now in the month of July. The ice is breaking away from the shores; but out in the fjords and in the bays it still lies unbroken and hidden under the snow. In the localities where the snow has not accumulated in too large quantities, small lakes now begin to form. It is the slush from the deeper lying strata, which now here and there reaches as far as the surface, and as the lakes have no connection with the water of the fjords, the water in the former is fresh. These lakes quickly extend in the direction of the wind, in that the small waves simply eat up the snow at the margins of the lake. In this manner elongated, sinuous channel-like lakes are formed, which may pass into a whole system of inter-connected channels.

The snow slush has only very little effect in dissolving the nearly fresh ice of the fjord, so that the snow and the snow slush rather serve to protect the ice against the warm air and the rays of the sun. Otherwise is it with the water of the channels. Here we

have the conditions for heating the surface. But the warm surface water subsides and has a dissolving effect on the fjord ice, and so the channels gradually melt through the upper layers of the ice and excavate beds for themselves.

Out on the fjord several large cracks have opened up. They often form from one season to another in the same places; in narrow passes from point to point, or between islets and skerries. Round the icebergs and islets small open cracks have formed, and everywhere there are breathing holes for seals and walruses.

The system of channels on the top of the fjord ice thus becomes connected with the waters of the fjord. The waters of the channels can to a certain extent be drained off, and thus the effect of the channels becomes similar to that of draining ditches. Consequently one may here and there on the fjord ice, in the course of the summer, meet with fairly tolerable travelling conditions. (Thus in August 1906 I made a short sledge trip on the outer part of Skærfjorden, at a season when the creeks and bays of the interior of the fjord were quite open, and in July 1907 I drove from Danmarks Havn, 15 km in a southern direction, across the fjord to Lille Koldewey). But in other places the channels may, at the same time, place very serious obstacles in the way of the traveller, even though after some searching one generally finds a place, where one can jump across. Besides the snow is very coarse-grained and the snow-crystals sharply angular, so that the dogs' paws are cut and bleed. The fjord ice does not lend itself to longer journeys during the summer season, among other things because it will nearly always be difficult to get to the shore, and because one cannot avoid encountering large impassable cracks.

The above description of the channels along the surface of the ice corresponds with the conditions, such as we have been able to observe them in Dove Bugt in the years 1907 and 1908. In the summer of 1912 I once more met with similar conditions in this place, and in July 1900 I remember having seen well developed channels on the ice north of Sabine Ø. On Skærfjorden in August 1906 one would hardly be justified in speaking of a system of channels, but rather of frequently occurring elongated lakes. The water in them was in many cases salt, so that there was a connection between them and the water of the fjord, which was also often directly visible. Here the channels were not fully developed, while the fact that the water of the lakes was salt might seem to indicate that they had arisen through melting taking place round breathing holes.

Of the conditions in the fjords further north we know very little,

Fig. 104. Water channels on the surface of the fjord ice.
Along the shore several parallel tidal cracks. Kap Bismarck. July.

Fig. 105. The fjord ice dissolving.
The fjord east of Danmarks Monumentet. Dove Bugt. July.

and have in the main to fall back upon conjectures. Jøkelbugten and Nioghalvfjerdsfjorden in reality belong to the marginal zone of the inland ice. Channels of melting water will consequently hardly be met with in that place, but on the other hand surface rivers as on the inland ice. Our limited knowledge of the conditions in Danmarks Fjord, Independence Fjord and Hagens Fjord only shows us that in this place the ice is generally, as far as great portions are concerned, several years old; we know that during the summer a channel of open water forms along the shores, and it is a reasonable supposition that the interior of the fjords likewise become free of ice in normal summers; but we know nothing of the manner in

Fig. 106. Elongated lakes on the fjord ice. Skærfjorden, August. In the background Rekvedøen.

which the last stages of the ice-melting of the summer appear on the great mass of ice out on the fjords.

In Frederick E. Hyde Fjord rather peculiar conditions seem to obtain. In the outer part of the fjord there had, as mentioned above, in 1907 accumulated an immense, fairly evenly distributed layer of snow, presumably several metres thick; but already 25 km inside the mouth the conditions were quite different. The snow here lay in downs which were one to two metres high and elongated in the direction of the fjord. In the hollows between the downs it is true that we generally met with snow, but very frequently we here found quite smooth ice, which showed that in this place there had in the previous autumn been a small lake on the ice, which was thus perennial. I am inclined to think that here we had to do with sikosak (for fuller details as to this see below), and that the "downs" owed their existence to well-developed "melting knolls" (see the

present volume Fig. 8, p. 15, Fig. 18, p. 25 and Fig. 28, p. 30 as well as the description pp. 25—27).

The channels on the surface of the ice represent one of the last stages of the fjord ice. Gradually the channels melt through; the bottom becomes full of holes, and the ice here is so weakened that it is ready to break up, as soon as the opportunity offers.

Already in the month of June the drift ice has commenced to set off from the shore and to make the passage free of fjord ice. In July, when the fjord ice has detached itself from land, one may expect to see the outermost part of the fjord opening up, in that the fjord ice breaks off, and begins to go adrift in an outward direction (see Fig. 86), but still the great mass of fjord ice forms one continuous sheet, the movement of which is prevented by islands, skerries and points. In August the innermost small bays and fjords are free of ice, or the ice in them is broken. The great mass of the ice out on the fjord is divided by a few cracks running the whole length; the channels are beginning to melt through, in short, the ice is crumbling.

The first føhn storm which comes along now breaks off large portions of the ice and causes the whole mass to go adrift, so that along the west and north shores a broad belt of open water may form.

The broken fjord ice has the surprisingly rapid motion of the drift ice. The wind and tidal currents set it adrift, causing it constantly to shift its position; where at a given moment one finds large stretches of open water, one may, a couple of hours afterwards, find the water blocked up with ice. The force with which the wind crushes the ice against the shore is very impressive. I have, in one case, seen how the fjord ice, during a summer blizzard, was crushed a long distance in across the land, while at the same time pushing a wall of pebbles and gravel before it.

We have now come to the last stage of the fjord ice, and it would very soon disintegrate altogether, were it not for the fact that the winter at this period begins to make itself felt. Even during the warmest month of the summer, that is July, the temperature is frequently below zero, so that new ice forms on the water, and during the latter half of August, when the mean temperature is about zero, the new ice becomes so strong that it can hold for several days and is only broken up by the wind. It therefore becomes dependent upon the casual weather conditions of the individual year, whether or not the fjord ice disappears altogether. Strong and steady winds at the end of August and the beginning of September will quickly clear Dove Bugt of the remains of the fjord ice, whereas the

result of calm weather will be that the last great ice floes are not broken up and permit the cold once more to make the broken ice one united whole.

Where the fjord ice remains throughout the summer and thus becomes perennial, the first condition for the formation of the sikosak — i. e. ice on the sea formed on the spot, simply by the fall of snow — is present.

When the weight of the deposited snow has pressed the fjord ice down to a certain depth, presumably about a couple of metres, the latter cannot, even during the hardest winter season, increase downward by freezing, and in case the ice is weighed further down, melting will take place throughout the year on the under surface.

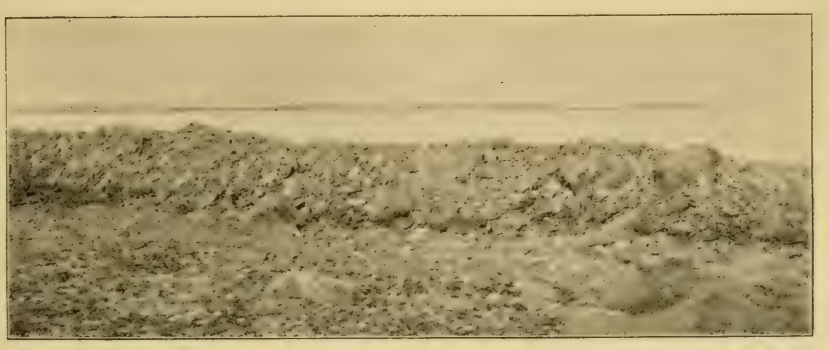

Fig. 107. Wall of pebbles and gravel, about 1 m high, formed by the fjord ice crushing in across land during a föhn storm. Germania Land. July.

The original fjord ice, formed by the freezing of the sea water, must consequently melt off, and that which remains is entirely due to the fall of snow.

As a matter of fact there may, in the coast sea and the fjords, form névés and glacier tongues in a manner corresponding altogether with those which form on land. The general condition for a formation of this kind is the same in both places, i. e. that the quantity of snow deposited exceeds the total waste of snow and ice, but in order that a considerable sikosak may form, it is a further condition that the ice is not to be broken up and to drift away.

From a letter from Freuchen I learn that the formation of the sikosak is a well-known phenomenon among the Eskimos in the fjords of the Cape York district. Here fjords may be met with into which no glaciers debouch, but which are nevertheless filled with a glacier having a well-developed system of crevasses. The Cape York Eskimos know that glaciers of this kind do not continue to exist, but that after an interval of many years they disintegrate and go

adrift, but only to form again in the years to come. According to Freuchen's description we are evidently at Cape York dealing with a sikosak, which at a certain stage has reached such dimensions that it rests on the bottom of the fjord throughout a considerable portion of its extent, as there could otherwise not be any progressive movement in it, and that a movement of this kind must be supposed to exist, is indicated by Freuchen's remark on the developed glacier crevasses.

The above-mentioned sikosak from Cape York described by Freuchen, corresponds well with the conditions of certain snow glaciers on Germania Land[1]), with the sole difference that the latter are to be found in localities above the level of the sea. The Cape York type of sikosak, which most nearly corresponds with the valley glacier, we have not met with in water areas in Northeast Greenland. On the other hand we have, in the southernmost part of Jøkelbugten and near Norske Øer, met with an apparently motionless sikosak, which should thus most nearly correspond with the névés on land, and it is reasonable to assume that the extremely heavy ice observed by de Gerlache between Ile de France and Norske Øer (see p. 413), likewise was sikosak. That also great portions of the ice in Jøkelbugten and Nioghalvfjerdsfjorden must be supposed to have been formed in the place itself from the snow has already been mentioned. Likevise it has been mentioned that according to Freuchen's observations in 1912 sikosak is to be met with in Hagens Fjord and Independence Fjord.

From the description given above of the ice conditions in the fjords of Northeast Greenland it will already be manifest that it is only for a very short period of the year, one month at most, that there is so much open water that the icebergs can go adrift.

Compared with other parts of Greenland the production of icebergs in Northeast Greenland must be said to be insignificant, in that a large portion of the surplus, which from the inland ice is discharged into the sea, is prevented from breaking up and drifting off by the practically speaking permanent coast ice, but instead of that spreads itself across the sea, in the form of enormous, partly floating ice fields, and melts away there (see this volume Die glaciol. Beob. der Danmark-Exped., chaps. I, II and IV). Only in the interiors of the fjords, where open water is formed regularly every summer, and on those parts of the outer coast, where the sea ice is broken

[1]) Die glaciol. Beob. der Danmark Exped., Kap VI, the present volume pp. 56—63.

right up to the shore, do we find the conditions necessary for the forming and breaking loose of icebergs.

Icebergs are formed in Dove Bugt from Soranerbræen, Bistrups Bræ and Storstrømmen; in the southern part of Jøkelbugten from Kofoed-Hansens Bræ and a couple of smaller glaciers, which penetrate Hertugen af Orleans Land; on the outer coast of Hovgaards Ø; from a couple of small glaciers in Ingolf Fjord; from the two long ice walls between Antarctic Bugt and Nordost-Rundingen; in Hagens Fjord and — according to FREUCHEN — in the interior of Independence Fjord from Academy Bræ and Nyeboes Bræ as well from a couple of small glaciers near Kap Grundloven.

On the east and south coast of Peary Land icebergs are, on the whole, hardly formed in any place.

The production of icebergs in the above-mentioned localities is altogether very small; only in Dove Bugt (Storstrømmen) and presumably also in Independence Fjord (Academy Bræ and Nyeboes Bræ) is the production considerable and as great as in the larger glaciers of West Greenland.

As indicated in the map the bulk of the icebergs of Storstrømmen drift away through the sound between Edvards Ø and Carl Hegers Ø. In the interior of the fjord[1]) in front of the glacier wall of Storstrømmen, there are, it is true, many icebergs, but they only occur singly and scattered at great intervals. West of Edvards Ø, where the fjord narrows, nearly 15 km south-south-east of Bræøerne, the icebergs are, on the other hand, so densely packed, that they almost form a regenerated glacier, whick closes the fjord like a plug. Further out in the sound, between Edvards Ø and Carl Hegers Ø, this collected mass of ice again dissolves into single icebergs, which are here so densely packed that only with some difficulty is it possible to make progress between them on a sledge. Not till east of Edvards Ø, where the sound opens up towards Dove Bugt, do the icebergs spread out so much that it becomes at all possible to keep the individual icebergs apart, when trying to count them.

The area on which the icebergs are densely packed is nearly 100 square kilometres, and so it is not unreasonable to estimate their total number as exceeding ten thousand.

From the sound south of Edvards Ø and partly also from the other sounds in the belt of rocks and islands round Teufelkap the icebergs spread over Dove Bugt. Part of the icebergs pass towards northeast and escape into the sea in the sounds past Danmarks Havn, while others pass in a southerly direction, and are stranded

[1]) In 1912 this fjord was named by me Borgfjorden (the Castle Fjord).

in great quantities at the south point of Store Koldewey, before they escape into the sea. A few of the south going icebergs continue along the shore towards the south, through the water between Hochstetters Forland and Shannon.

The large number of icebergs formed from Storstrømmen in reality only take up a little space in Dove Bugt, where the general impression is that only here and there does one come across an iceberg. From Stormkap, at an altitude of about 40 m I have, without a telescope, only been able to count about three hundred icebergs, which also shows their scattered position.

As stated above, it is only possible to reckon with at most one month in the year, in which there is so much open water in Dove Bugt that the icebergs may go adrift, and as a rule they are not even able to make use of the short period of liberty granted them by the fjord ice, because of their being stranded.

The immediate impression received from a consideration of the difficult conditions under which the icebergs of Storstrømmen must work their way, first through the narrow and densely packed sound between Edvards Ø and Carl Hegers Ø, and later on through Dove Bugt, is that the large icebergs in this part of Greenland must be able to attain a very considerable age, before they disintegrate.

In Medd. om Grønl., IV, p. 103, K. J. V. Steenstrup published some experiments on the melting of the glacier ice in sea water, and he proved that quite small fragments of calving icebergs only have a very small power of resistance in the sea water. A fragment of ice of about 11 kg, which was lowered into sea water at a temperature of about $\div 1.3$, lost from the very beginning about 1 % of its own weight per hour.

The absolute melting must be proportionate to the surface of the part of the iceberg lowered into the water, and the loss of weight in proportion to the weight of the entire iceberg thus becomes inversely proportional to the linear measures. The linear measures of one of the larger icebergs of Storstrømmen may be estimated at about a thousand times the measures of the fragment of ice used by Steenstrup for the melting experiment, according to which they thus ought to reach an age about a thousand times that of the fragment of ice used in the Steenstrup experiment, i. e. nearly ten years. As will be shown in the following, it must in reality be supposed that the icebergs may reach an age many times greater.

The hydrographic measurings undertaken by Trolle in Dove Bugt at depths which can be taken into consideration here, show a temperature considerably lower than $\div 1.3$. In particular I will draw attention to the two hydrographical stations LVI from 28/V 1908 and

LIX from 11—12/VI 1908[1]), the series of temperature of which are as follows:

Series LVI, 28/V 08, lat. 76°51′ N, long. 19°51′ W.

Depth, metres	Temperature	Freezing point temperature
2	÷ 1.72	÷ 1.74
25	÷ 1.65	÷ 1.75
50	÷ 1.69	÷ 1.77
75	÷ 1.70	÷ 1.78
100	÷ 1.61	÷ 1.80
125	÷ 1.39	
150	÷ 1.19	
180	÷ 1.08	
215	÷ 1.02	

Series LIX, 11—12/VI 08, lat. 76°46′ N, long. 19°00′ W.

1.5	÷ 1.74	÷ 1.75
25	÷ 1.72	÷ 1.76
50	÷ 1.72	÷ 1.77
75	÷ 1.71	÷ 1.78
100	÷ 1.63	÷ 1.80
125	÷ 1.62	÷ 1.80
150	÷ 1.62	÷ 1.81
175	÷ 1.61	÷ 1.82
200	÷ 1.60	÷ 1.82

It will appear that particularly in the last-mentioned series the conditions of the melting are far more unfavourable than in the case of the STEENSTRUP experiment. However, it is in reality still more unfavourable than the series of temperatures show. The freezing point temperatures are computed by means of the quantity of chlorine contained in the water samples taken, but as also proved by STEENSTRUP[2]) by means of direct measurements the quantity of chlorine in the mixture of melting water and sea water surrounding the icebergs will be perceptibly smaller than in the sea water itself, and the freezing point will consequently lie higher, and the mixture — according to the circumstances — thus contributes a more or less effective protection against the melting. In the case of the STEENSTRUP experiment, for which a fragment of ice of 2 to 3 cubic decimetres was used, this circumstance of course could not make itself felt; on the other hand it undoubtedly plays a part in the melting

[1]) ALF TROLLE: Hydrographical Observations from the Danmark-Ekspedition. Medd. om Grønl. XLI, pp. 338 and 339.

[2]) Bidrag til Kendskab til Bræerne og Bræisen i Nord-Grønland, Medd. om Grønl. IV, p. 96.

of a larger iceberg, and more especially the significance appears in localities such as the sound between Edvards Ø and Carl Hegers Ø, where the icebergs on a large area are quite densely packed.

The age of about ten years, which — by a direct application of the results of the Steenstrup experiment — we arrived at in the case of one of the larger icebergs of Storstrømmen, must thus be supposed to be many times too low; in reality there seems to be nothing unreasonable in the supposition that they may reach an age of more than a hundred years.

It was mentioned above that the icebergs in the inner part of the sound between Edvards Ø and Carl Hegers Ø were so densely packed that they formed, so to speak, a floating, regenerated glacier, which gradually dissolved into single icebergs, only after they had got further out into the sound. Similar conditions may, by the way, be observed in the large ice fjords of West Greenland. This disolving of the "regenerated glacier" is partially explained by the aforesaid observations and reflections on the melting of the icebergs.

Under the "calving" enormous quantities of greater or lesser fragments of calving ice are formed besides the icebergs proper, and it is these fragments which fill up the intervals between the larger icebergs in the interior of the sound between Edvards Ø and Carl Hegers Ø, so that the idea of a regenerated glacier presents itself. By and by, however, the ice fragments and smaller icebergs melt, and one therefore gets the immediate impression that the icebergs further out in the sound again separate from the compact ice mass.

An important factor in the melting process of the ice is undoubtedly the ruptures due to the frost. It is a well-known fact that on a day with a summer temperature one may in the great ice fjords of Greenland at any moment hear a sound which bears a striking resemblance to that of gun fire. That sound is due to the icebergs "calving", in that melting water from the part of the iceberg lying above the surface of the water penetrates the cracks, where it freezes and then breaks off part of the iceberg. It is not so well known that the icebergs — and the small ones in particular — on occasions of this kind may become entirely "pulverized" and dissolve into an aggregate of single glacier granules, or smaller lumps. However, the usual thing is that only a small part of the iceberg breaks off and falls into the water. The iceberg, which thus loses its equilibrium, then starts a series of quite slow oscillations, like a pendulum, and as a rule ends by settling in a position deviating somewhat from the original equilibrium. For an iceberg suddenly to turn over and veer round, such as has often been related, is a phenomenon which rarely occurs.

Natural phenomena of such a violent character as the calving of icebergs, as a rule stimulate the imagination strongly. It is, therefore, not quite easy from a layman to get an objective picture of what has really taken place, and therefore I venture to think that the following little personal experience may be of interest from a scientific point of view.

On July 28th 1912 I had moored a large iron lighter loaded with goods weighing sixteen tons to an iceberg stranded in Dove Bugt near Stormkap. The moorings were made fast to an ice anchor on a terrace projecting from the iceberg, and the surface of which lay about two to three metres above the surface of the water. Sailor LARSEN and myself were carrying some goods, which were to be put ashore at Stormkap, down into a motor boat lying alongside the lighter. While thus occupied we heard the loud report of a calving on the opposite side of the ice colossus, and shortly afterwards we observed how the part of the iceberg rearing above the water was veering towards us. The platform to which our ice anchor was made fast, sank below the water, and in order to prevent the lighter from being crushed down by the moorings, we made ready to slip the latter. It was quite clear to us that a catastrophe might occur; but we never thought that there might be time to get away, before it happened. After a few minutes the terrace with the ice anchor again emerged from the water, and it was now quite evident to us that the iceberg performed a kind of pendulum oscillations, and that the chances of an impending peril were in reality very small. However, we did not dare to run any risks, and so we slipped the moorings and hauled the lighter a couple of hundred metres away from the iceberg. While this was being done, the terrace rose several metres above its original position, and then again swung quite slowly below the water. As we were very loth to lose our anchor and moorings, we went back to the iceberg with the motor boat only, and when the terrace emerged once more, we jumped on to it, clutched the anchor and jumped back into the boat, without having to join in the upward oscillation of the iceberg.

When the iceberg became settled at last, it had performed a rotation of about ten degrees. Besides it had got clear of the bottom and drifted further out into Dove Bugt.

Unfortunately I neglected to take the time of the oscillations, which would have been quite possible without any risk whatever; but from the description given above, it will be at least possible to get a direct impressiou of the extreme slowness and deliberation of the movement.

Only in a single case did the members of the Danmark-Eks-

pedition measure the altitude of an iceberg which was stranded in the neighbourhood of Stormkap, in water the depth of which was about 90 m. The altitude was 36 m, which is rather striking, considering the shallowness of the water.

A few table-shaped icebergs, formed from Storstrømmen, must as regards their dimensions be reckoned among the largest in Greenland. On the other hand the icebergs of Storstrømmen have no very considerable altitude above the level of the sea; neither in 1906—08 nor in 1912 have I seen a single iceberg the altitude of which I would estimate at 50 m.

It must be supposed that only a very small part of the icebergs of Dove Bugt ever leave it. The few which reach the coast sea are so greatly reduced that they dissolve comparatively quickly.

The icebergs forming further north have a still more circumscribed existence. However from the southern part of Jøkelbugten a few, not quite insignificant icebergs may reach the mouth of Orleans Sund, and from there, in particularly slack ice years, may continue the journey out into the coast sea; on the other hand, one may venture to say that it is only on very rare occasions that an iceberg escapes from Independence Fjord or Hagens Fjord into the drift ice. On the two occasions when by widely different routes I have crossed the mouths of the fjords inside Wandels Hav, I have not seen a single iceberg. But Hagen mentions — presumably as something unusual — the existence of an iceberg at the mouth of Hagens Fjord. The small icebergs which may come from Hovgaards Ø, the small glaciers on Holms Land, Ingolfs Fjord and the ice wall between Antarctic Bugt and Nordost-Rundingen are so insignificant that they cannot have a very long life.

The icebergs in the coast sea north of the 74th parallel are therefore small and rather rare.

The Coast Land.

When in 1906 we left home, we expected to find in Northeast Greenland a large ice-free coast land. We knew that from Scoresby Sound a comparatively broad coast land extended in a northern direction as far as the 75th parallel, and probably further; we knew that at Navy Cliff Peary had met with a considerable ice-free stretch of land, and we had good reason to believe that Peary Land at least did not contain any continuous inland ice, even though there were fairly large ice-covered areas. We knew that the snow fall decreased towards the north, and in this very circumstance we looked for the explanation of the fact that Peary Land was not covered with ice to the same extent as the rest of Greenland.

Fig. 108. Alpine landform The fjord south of Ardencaple Inlet between Kap Negri and Kap Buch. May.

Fig. 109. Alpine landform. Barthberge with Wildspitze seen from Ardencaple Inlet. May.

It consequently came as a surprise to us, when it turned out that in Northeast Greenland there is no continuous ice-free coast land to speak of between the 76th and the 82nd parallels. A glance at the map shows that Dronning Louises Land, Hertugen af Orleans Land and Lamberts Land must in reality more particularly be looked upon as nunataks in the inland ice, and only Germania Land and the coast from about 79°40′ to 81° appear as an ice-free coast land in the ordinary sense of the word. The cause of this poverty of coast land is that on long stretches there is an absence of continuous coast mountains, which might force the inland ice to seek an outlet through comparatively narrow valleys. In particular on two stretches, from 78° to 79°40′ and in the northern part of Kronprins Christians Land, does the inland ice spread itself fairly unhindered by the relief of the surface, and conceal the coast stretches from our view.

Northeast Greenland is built of gneiss. Here and there sediment occurs in smaller localities; but these are so scattered, and the areas are so small that from a topographical point of view they play an inferior part. It is therefore first and foremost the gneiss and the external influences to which it has been exposed throughout the years, which determine the character of the landforms. Peary Land must in the main be supposed to have been formed of sedimentary rocks, which are, however, nearly equal to gneiss in their power of resistance.

The alpine landform.

By far the greater part of the present ice-free coast land has in former times been covered with inland ice; only certain well protected tracts, certain highly situated parts or a few high peaks projected like nunataks through the ice. These mountainous parts and peaks continued through the European-North-American glacial period to be exposed to the disintegrating influence of the atmosphere, but in return they were exempted from the smoothing and polishing erosion of the ice. A characteristic feature of the alpine landform is the great quantity of tall, pyramidal, sharply angular and as a rule inaccessible mountains with *cirques* (*corries*, *kessel*) filled up with névés. The longitudinal valleys are often deeply indented, winding and filled with glaciers.

South of Jøkelbugten the Danmark-Ekspedition has only in a single place been able to prove the existence of this landform, that is in Barth Berge (altitudes about 1600 m), but it is possible that certain parts round Bessels Fjord and Ardencaple Inlet must be included in this group. In the same manner we are inclined to class

the highest peaks determined by us on Dronning Louises Land (altitudes about 2000 m) with this landform. When in 1913 I went across Dronning Louises Land, it turned out that this supposition was correct, at any rate as far as a single locality was concerned, and at the same time I discovered at the western outskirts of Dronning Louises Land, on about 76°30′ n. lat. and 26° w. of Grw., a large quantity of nunataks having the pronounced characteristic of alpine landforms[1]). The highest peaks in this place, Gefionstinderne, were on the voyage roughly computed at 2500 to 2700 m; they are among the highest known mountains of Greenland.

Fig. 110. Alpine peaks. Trækpasset in Store Koldewey. April.

North of Jøkelbugten the alpine landform becomes more general; it thus occurs everywhere in the interior of Djimphna Sund, Hekla Sund and Ingolfs Fjord, but not at the outer coast off these fjords (the heights of the alpine landform from 800 to 1800 m). Not till on Peary Land at Kap Clarence Wyckoff does the alpine landform stretch as far as the outer coast, and then it follows the trend of the latter as far as the map of the Danmark-Ekspedition goes towards the north. G. B. Schley Fjord and Frederick E. Hyde Fjord — Fig. 51 — are pronounced alpine fjords; Dannebrogstinde (1050 m) — Fig. 53 — and Stjernebannertinde (1370 m) are typical alpine peaks. The highest peak measured on Peary Land is situated in Daly Mountains (1400 m); but I have seen peaks which I estimated at more than 2000 m.

[1]) See map sketch to I. P. Koch, Glaciologiske Iagttagelser i Nordgrønland 1912—13. Meddelelser fra Dansk geologisk Forening, vol. IV, Kjøbenhavn 1915, and also Zeitschrift für Gletscherkunde, Bd. X, 1916.

Through our observations of the occurrence of the alpine landforms it is possible to get certain ideas of the former dimensions and extent of the inland ice in Northeast Greenland.

The nunataks west of Dronning Louises Land only seem to have been very little influenced by a former higher ice level. The lowest nunataks, which only projected as much as about fifty metres through the ice showed, it is true, a tendency to more rounded and softer landforms, but we did not find a pronounced moutonnéed landform in this place. It is not reasonable to suppose that the inland ice in this place has ever lain more than a couple of hundred metres higher than it does now. The present altitude ot the surface of the ice at the nunataks is between 1800 and 1900 m. An increase in the thickness of the ice of a couple of hundred metres will, in reality, be sufficient to make Dronning Louises Land disappear, with the exception of the very highest peaks.

In the same degree of latitude as the above mentioned nunatak land, but 150 to 200 km more to the east, lies the island of Store Koldewey, the highest point of which is 971 m. This island has been covered by inland ice, and considering the depth of the sea west and east of the island we may, therefore, take it for granted that in this place an ice cap has melted off, the thickness of which has been 1000 to 2000 m. The thickness of the ice, which has disappeared, thus seems to be five to ten times as great at the outer coast as in the western part of Dronning Louises Land, which observation seems to point towards the fact that the inland ice in the central part of Greenland in the glacial period, has not practically been more powerful than it is now. That the coast land on about 77° has been covered by an ice cap of 1000 to 2000 m in thickness corresponds well with the fact that the country during the alluvial period has risen about 400 m. The weight of a gneiss mass of 400 m in thickness will nearly correspond with the weight of an ice cap of 1200 m.

If we follow the occurrence of the alpine landform in a northern direction, we find not only that the alpine peaks become lower, but also that the lowest part of the alpine landform approaches very nearly to the level of the sea. From this we see that the ice cap of the glacial period in the northernmost part of Greenland has scarcely been of any very considerable thickness, and so has hardly reached beyond the sea in the same degree as farther south.

Ice period landforms.

Before going on to mention the landforms created by the inland ice, I must premise a few remarks on the manner, in which the

inland ice conveys its supplies from the central parts of Greenland out to the coast.

The surface of the marginal zone of the inland ice is undulating. The ice rises in large, but little pronounced terraces, towards the interior of Central Greenland, and thus vaguely and roughly reflects the relief of the underlying land. In the marginal zone we can still faintly trace the mountain ranges and the chief valleys, and further one may see, how the great ice streams, which as glaciers pass beyond the circumference of the inland ice, continue as streams up to more than a hundred kilometres into the inland ice. The stronger motion of the stream appears immediately from the systems of crevasses, whereas the surrounding areas of ice lie comparatively quiescent.

If one gets inside the marginal zone, the reflection of the relief of the underlying land ceases after a while. The interior of Greenland is a quite even névé without crevasses or the least indication of the forms of the terrain, which it conceals. However, to deduce from this that the ice in the interior of Greenland is in a quiescent state would be incorrect. In the upper layers the motion is chiefly vertical ɔ: the layers sink slowly downwards to be carried away through large ice-currents in the deep. These currents follow the large depressions of the country, irrespective of whether in this manner they come to pass across isolated peaks, smaller plateaus or low spurs from the ranges of mountains.

In spite of the quite homogeneous motion in the surface of the névés of Central Greenland, we must thus suppose the motion in the deep to be widely different in the different places; and so also the landforms, which appear when the inland ice melts away, are of a different type.

Keeping the map of Northeast Greenland in view it is not difficult to construct the chief features of the lines of motion followed by the inland ice, when it extended beyond the coast land and practically concealed it altogether; it is Dove Bugt and Jøkelbugten, which have formed the two chief drains.

Storstrømmen and Bistrups Bræ existed then, as they do now, but concealed in the deep below an inland ice which extended over Dronning Louises Land and Germania Land. After having, as they do now, joined off the middle of Dronning Louises Land, they bent towards the east, across Dove Bugt, the northern part of the united current passing across the country north of Edvards Ø, whereas the southern part swept across the islands between Teufelkap and Kap Niels. At the same time smaller ice currents in the deep passed through Hellefjord, Mørkefjord, Sælsøen and Annekssøen into the

northern part of Dove Bugt, whereas the ice above the range of mountains between the fjords and lakes mentioned lay comparatively quiescent.

The difference of altitude between the ridge of Store Koldewey, south of Bergs Fjord, and the sea bottom in Dove Bugt is 1000 to 1400 m. Store Koldewey, therefore, lay as an immense barrier, which was, it is true, concealed by névés, but which the east-going ice currents could not pass. Part of the ice currents of Dove Bugt consequently flowed in a southerly direction along Store Koldewey. North of Bergs Fjord the hills on Store Koldewey do not rise much above 400 m, whereas the corresponding depth in Dove Bugt, judging by the existing soundings, does not materially exceed 200 m. Here the ice currents could break the resistance offered by the terrain; in the northern part of Dove Bugt the motion of the ice therefore continued towards east across the northern part of Store Koldewey (see Fig. 94) and the low coast land and the small islands round Danmarks Havn.

The time which has passed since the coastland was denuded of ice is so short, that since then only one material change can have taken place in the appearance of the land, that is the one, which is due to the circumstance that great stretches of the present coast land, after the ice period, have risen above the level of the sea. This fact however only in a less material degree affects the landforms, and so in Northeast Greenland one gets an immediate and strong impression of the fact, that the landforms created by the ice may be referred to two types, very different in aspect: The moutonnéed (rounded) rocks, corresponding with the localities where the motion of the ice has been strongest, and the plateau, corresponding with the stretches where the motion of the ice has been very slight. Between these types there are, however, also transition forms.

The moutonnéed landform.

Seen at some distance the moutonnéed landform often, in a surprising degree, reminds one of the hilly (moraine) landform, so common in the North-European lowlands. We find the same rounded, dome-shaped or elongated forms, the same soft transitions between ranges of hills and valleys. But if one stands in the middle of a stretch of moutonnéed land, the impression becomes a different one. The hills then prove to consist, not of loose moraine sediments, but of more or less denuded bedrock, which is polished smooth by the ice, to such an extent that its surface has become as even as a flagged but undulating ground. Of the loose material which the ice

left on the peaks, when it melted off, the fine grinding powder has been washed down into the hollows, and only a few scattered, larger or smaller, loose stones remain.

The western side of the peaks, the *stossseite* (the exposed side) is generally the steepest, and here the grinding process has been strongest.

In the hollows between the peaks the bedrock is covered with loose material, which has partly been left there by the ice, and partly has been washed down from the peaks. Where in its time the ice has overridden a fairly large ridge, for instance Varderyggen or the northern part of Store Koldewey, it is a considerable quantity of loose *débris* which one meets with on the lee side. The loose material is possessed of a relatively high degree of mobility. This is partly accounted for by the fact that the sparse vegetation cannot to any material extent help to make clay, sand and gravel adhere to the slopes, and partly by the high arctic climate, the result of which is that the bottom is frozen to a great depth all the year round. Only in the months July and August the upper layer is thawed to a depth of a few decimetres. As the water cannot escape in a downward direction through the frozen bottom, a slush is formed on the slopes, where there is ample drainage from the melting snow above, which slush slowly glides downwards on the frozen substratum. Attention is directed to this motion in the surface through the fact, that one very often comes across flat stones, which stand on edge, and the greater part of which projects freely from the ground. This seemingly unnatural position occurs, when during the gliding motion the front edge of the stone meets with resistance, for instance another stone, which adheres to the frozen bottom, and the upper part of which projects into the slush. The pressure of the gliding masses then overturns the flat stone. In quite exceptional cases do we meet with large areas, of a plain-like character, which glide in this manner. This is for instance the case south-west of Hellefjord, where a single large bottom opens towards the ice fjord of Storstrømmen, off Bræøerne. This bottom, the area of which is nearly 30 square km, is covered with grass, and its declivity is only a slight one. Nevertheless the upper layer of earth in the bottom of the valley glides slowly down towards the ice fjord.

On the lee-side of the larger ridges, where there are not only more considerable quantities of loose material, but where there is also an ample supply of melting water, the loose material has a strong tendency towards filling up all the depressions in the surface. The terrain here forms terraces with nearly horizontal surfaces; there are only few and small lakes, presumably shallow; still the

Fig. 111. Moutonnéed land seen at some distance. Germania Land. July.

Fig. 112. Moutonnéed landform. Germania Land.

Fig. 113. Polished bedrock. Lille Koldewey. April.

Fig. 114. The *stossseite*. Western slope of Harefjeldet. March.

Fig. 116. Moutonnéed land. Small lake frozen over.
Lille Koldewey. September.

Fig. 117. Moutonnéed land on Lille Koldewey. September.

lakes are far greater than the pools and ponds, which are met with in hundreds in other parts of the moutonnéed landform. The moutonnéed rock only appears in the light of day as detached, more or less projecting rocky islands.

In the immediate neighbourhood of the coast the moutonnéed landform may assume a materially different aspect. The belt of rocks and islands girding the coast east of Danmarks Havn is a case in point (see Pl. II, Danmarks Havn and Environs). In this place we do not meet with continuous ranges of hills, but with great quantities of detached, low, rounded hills with small irregular depressions in

Fig. 115. Frost-cleft stone (gneiss). Effect of the gliding slush in connection with thawing and refreezing of the ground.

between. Here there is not sufficient material available for the levelling of the depressions; instead of that they are partly filled up with a large quantity of quite small lakes and ponds, the surfaces of which are often only a few metres above the level of the sea.

The above description of the moutonnéed landform refers to Germania Land and the belt of rocks and islands in Dove Bugt. The greatest altitudes in the moutonnéed landform here, only in exceptional cases exceed 600 m, whereas on Dronning Louises Land one may in this landform meet with altitudes of 1000 to 1200 m, though it must not be inferred from this statement, that moutonnéed landforms cannot be met with at greater altitudes. There are, as mentioned above, quite gradual transitions to the plateau landform, the altitudes of which reach 2000 m, and even in these altitudes the

occurrence of examples of less pronounced moutonnéed forms is not excluded.

North of Germania Land the moutonnéed landform looses a great deal of its significance as a feature of the landscape. All of the groups of islands in Jøkelbugten, including Norske Øer and the eastern part of Lamberts Land, still form extensive rounded ranges (see Fig. 66, Nordre Depot), but already on Hovgaards Ø the pronouncedly moutonnéed landform is restricted to small areas near the coast, and further north moutonnéed rocks are only met with here and there at the coasts, presumably also everywhere on islands

Fig. 118. The eastern spur of Lamberts Land. May.

and skerries, as for instance on Prinsesse Thyras Ø at the mouth of Danmarks Fjord.

The plateau landforms.

The western part of Germania Land between Hellefjord and Kap Récamier forms a nearly horizontal plateau, the altitude of which above the level of the sea is 800 m. The declivity towards east is rather steep; towards west the plateau slopes gently in the direction of the inland ice. The surface of the plateau is slightly undulating; the solid rock is in this place completely hidden by loose stones; clay does not occur at all; gravel and sand only appear sporadically in quite small quantities among the stones. The bulk of the loose stones are products of disintegration belonging to the place itself; still, also blocks of sandstone occur and of a sort of red granite, which is not indigenous and therefore suggests transport by the ice.

Fig 119. Plateau landform. The 800 m high plateau with the cleft of Mørkefjord seen from the top of Danmarks Monumentet. May.

Fig. 120. Plateau landform. Danmarks Monumentet seen from the east. To the right Mørkefjord, to the left Pustervig. May.

Fig. 121. Plateau landform. The 800 m deep cleft of Mørkefjord seen from the top of Danmarks Monumentet. May.

Fig. 122.

Fig. 123.

Plateau landform. From the banks of Mørkefjord. May.

Fig. 124. Plateau landform.
Danmarks Monumentet seen from Stjernefjeldene across Pustervig. May.

Fig. 125. Plateau landform.
Teufelkap. May.

Fig. 126. Plateau landform. Valley across Store Koldewey. Trækpasset. May.

Fig. 127. Plateau landform. Head of Smallefjord Ardencaple Inlet. May.

Fig. 128. Plateau landform. Kap Reinhardt. Ardencaple Inlet. May.

Fig. 129. Plateau landform. Kap Reinhardt. Ardencaple Inlet. May.

Fig. 130. Plateau landform. Kap Jungersen. Amdrups Land. April.

Fig. 131. Plateau landform. Mallemukfjeldet. Holms Land. April.
Drawn by Bertelsen from one of his paintings.

Water courses do not occur up on the plateaus; on the other hand one may here and there come across a small lake.

The plateaus of Germania Land are intersected by three deep clefts, very similar to crevasses, with steep, rocky walls; two of these clefts lodge Annekssøen and Sælsøen, the third is partly filled up by Mørkefjorden. The considerable glacial activity, wkich has taken place through these depressions, appears partly from the worn and rounded walls of rocks, of which in particular the north side of the Danmarks Monument is a splendid example, partly also from the frequently occurring moraines. Considerable lateral moraines are thus to be found near the Danmarks Monument, west and south of Rypefjeldet, at the east point of Væderen (the Ram) and along either side of Sælsøen. Terminal moraines occur at the western end of Sælsøen, and in the eastern part of Annekssøen; in both of these places the moraines stretch like an arc across the lakes and reach 5 to 10 m above the surfaces of the lakes. Also at the mouth of Mørkefjord, at the eastern point of the Danmark Monument, there is a terminal moraine, which like two broad parallel bars stretches across the mouth of the fjord, with a depth of water of 1 to 2 m.

With the plateau landforms must further be grouped the just now described area between Annekssøen and Hellefjord, Store Koldewey south of Bergs Fjord, large stretches of Dronning Louises Land, a large part of Hertugen af Orleans Land, the greater western part of Lamberts Land, as well as certain stretches of Holms Land (Mallemukfjeldet) and of Amdrups Land. In the two latter localities the plateaus consist of sand stone.

Transition forms.

As mentioned above the typical plateau landforms occur in localities where the ice has upon the whole been comparatively quiescent, whereas the typical moutonnéed landforms indicate a strong glacial action. It then follows, as a matter of course, that all sorts of transitions are to be found between these two extremities.

These forms of transition, to which belongs the country between Skærfjorden and Jøkelbugten, as well as the eastern tracts of Germania Land, consist of undulating mountain areas of 300 to 600 m altitude. They are grey and bleak stone deserts, the surface of which consists of loose stones and gravel, through which the worn and rounded rock projects here and there. Now and then one may come across a small lake or a narrow water course, but apart from that the only enlivening factor are the perennial snow drifts, which like white splashes are strewn all over the grey land.

With the transition forms between plateau and moutonnéed land-

forms must be classed Moskusoksefjeldene (the musk-ox mountains) the greatest altitude of which is 578 m, and which, as shown on the map, form a natural continuation of Store Koldewey.

Among landforms dating from the glacial period should still be mentioned the moraine deposits along the west side of Germania Land and Hvalsletten.

Generally the moraines along the ice margin consist of deposits with a heavy mixture of clay, which however in a few places, for instance at the interior of the ice fjord of Storstrømmen, may assume the character of a wall. The deposits along the ice margin, as nearly everywhere in Germania Land, consist of the

Fig. 132. From the eastern tracts of Germania Land. August.

ground moraine which remained after the melting of the ice. The peculiar characteristic of the latter is only that they are to be found in greater quantities than in most of the other places, that they are less washed out and disintegrated and less overgrown, and so generally speaking present a fresher and more original appearance.

Characteristic features of the landforms along the ice margin are the 20—40 m high, as a rule inaccessible, wall of ice, which is nearly everywhere black with moraine slush, the clayey marginal lakes and the marginal streams.

Northwest of Annekssøen the moraine landforms are of quite a peculiar character, which has been described in details and illustrated in "Die glaciol. Beobacht. d. Danmark-Expedition", pp. 43—48 of the present volume. That which takes place at the ice margin northwest of Annekssøen, in the characteristic and to us so heterogenous landform, is the melting off of the remains of the ice streams, which once worked their way through the valley of Annekssøen and through the valleys on either side of Kap Récamier. The ground

Fig. 134. Hvalsletten and eastern end of Sælsøen. Germania Land. Latter half of June.

Fig. 135. Hvalsletten. Latter half of August.

moraine at Annekssøen rests on a fragile sediment, consisting of limestone and coal, which the ice has thus not been able to erode, and yet it has at the same time had sufficient strength to polish the near and somewhat more highly situated gneiss rocks immediately east of the sediments.

Hvalsletten. Through observations of the heights of the strand lines above the sea, it has been possible to form a clear conception of the fact that Germania Land after the European-North-American

Fig. 133. Wall of limestone with layers of coal; on the top moraine deposits. Near the margin of the inland ice at Annekssøen. May.

period has risen about 400 m (see Fig. 70). This rise, which is the simple consequence of the melting of the ice, has however not kept pace with the melting itself, but in consequence of the inertness of the crust of the earth it has been greatly retarded. Great stretches of Germania Land have thus in the alluvial period been below the surface of the sea. The traces, left by the sea, are generally confined to more or less effaced strand lines and to the apperance of shells; as regard the landforms these traces of the sea are of no real importance. Only in a single locality, in the hollow between Moskusoksefjældene and Sælsøen, does there appear a plain 20 km long and about 10 km broad, which has been formed below the sea by the melting off of the ground moraine from the floating inland ice, in the same manner in which to-day this melting off must take place in Jökelbugten.

The altitude of the plain above the level of the sea near Trekroner is 40 to 45 m; from here it slopes quite evenly down towards Dove Bugt. The surface consists of stone and gravel, intersected by rivers, which have excavated deep, sharply defined riverbeds.

The name of this plain owes its origin to a stranded whale (probably a Greenland whale) the skeleton of which was found a few kilometres from the shore.

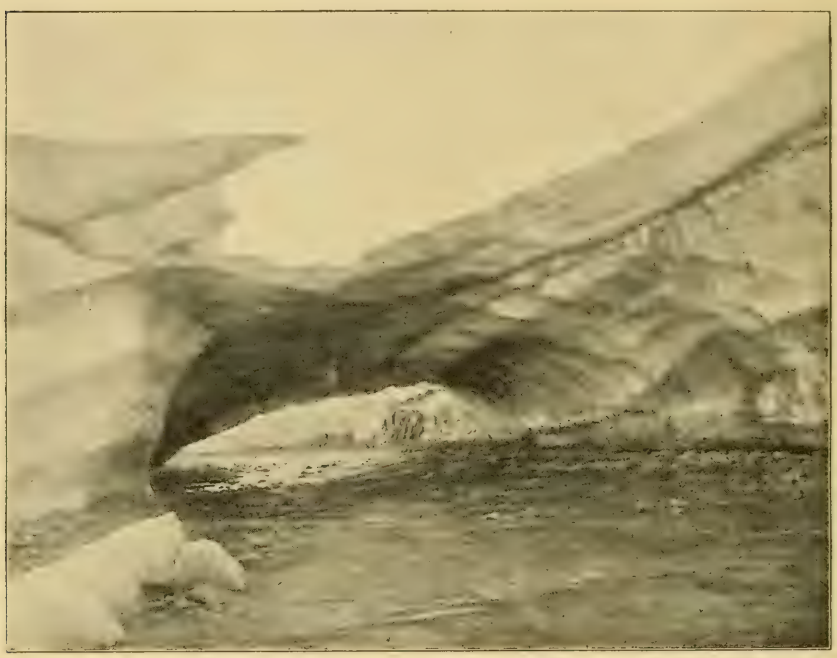

Fig. 136. Ice bridge. Germania Land. July.

Lakes and water courses.

Small lakes, ponds and rivulets occur in very great numbers in the moutonnéed rocks along the coast. In the terrain measured by Lindhard and myself from June 28th to July 4th 1908, west of Stormelven[1]), it will be possible, in an area of about 16 square kilometres, to count about thirty little lakes and water holes and a very great number of rivulets. The result of the high arctic climatic conditions is, however, that the small lakes and rivulets so to speak only exist for a short period of the year, but during this short period they play an extremely great part, in that an essential portion of the fauna and vegetation of Northeast Greenland is bound up with them.

[1]) Medd. om Grønl. XLV, No. 1, Pl. VII.

During the first half of June the melting of the snow begins; the moisture accumulates in the snow, and the water begins to ooze from the snow drifts. A sudden thaw does not occur, but the melting water accumulates in the rivulets, which in June reach such a magnitude that many of them become troublesome obstacles in the path of the traveller. During the first half of July the water courses attain their maximum; in many places they sweep across bogs and meadow tracts and flood the latter (see Fig. 79). But already in the latter half of July they decrease to a very perceptible degree, and in September, when the melting of the snow ceases, only the larger of them linger on. From the beginning of October all the little rivers cease to run. The beds of the rivers, which are now either quite dried out or covered by a thin crust of ice, frozen to the bottom, are soon hidden under the winter snow, which fills them in such a manner, that hardly even a faint hollow in the surface of the earth betrays their existence below the snow. This snow, which in the winter fills the beds of the small arctic rivers, in the summer give them a characteristic stamp. The watercourses which every year must excavate and melt a bed for themselves in the snow, in this manner are often made to float in a deep channel, which on either side is bounded by steep walls of snow, and spanned by more or less safe snow bridges. The snow bridges which may keep throughout the summer, in the course of the autumn assume an ice-like character; the larger of them may then form long

Fig. 137. River bed excavated in the snow. Danmarks Havn. June.

tunnels of splendid ice arcs, through which the river flows. Under particularly favorable conditions the tunnels assume the shape of extensive ice grottoes, the gorgeous splendour of which suggests fairy land. The phenomenon is exhaustively described and illustrated in the present volume, "Die glaciol. Beobacht. d. Danmark Exp." chaps. VI and VII.

The existence of the small lakes is analogous with that of the rivulets. In the month of June, when the country is strongly heated by the steady and powerful solar radiation, the melting of the ice progresses rapidly. At the end of June and the beginning of July

Fig. 138. Rivulet. Danmarks Havn. July.

the ice has disappeared, and the lakes and bogs now form a favourite resort of a great number of aquatic fowl. Already at the end of August the freezing begins, and from September the lakes are frozen over.

One might be tempted to believe that the small lakes would very easily freeze to the bottom, because the ground round and under the lakes must have a temperature, which is several degrees below zero, and this circumstance occasions a cooling off of the water from below. The measurings available of the thickness of the ice on the lakes do not offer sufficient hold for an estimation of the matter, whereas one may get some information from the conditions in a small lake near the harbour of the ship, where for some time we went to fetch water. The greatest depth of water in the lake is

about 4 metres. According as the winter progressed, we had to break the ice in greater and greater depths in order to get water. When the ice attained a thickness of two to two and a half metres, the work of breaking it became so difficult that we gave it up, and instead of that we melted ice in order to get water. As far as I remember, that was in the month of January. From this it might seem, as if a depth of three metres is the approximate limit within which the lakes freeze to the bottom. It must then be supposed that a very large number of the small lakes in the course of the winter freeze to the bottom, to which state of affairs the organic life in them must consequently be adapted.

The larger lakes and water courses. In Germania Land there are two very considerable lakes: Sælsøen, which is 1 to 3 km broad and about 50 km long, and Annekssøen, about 1 km broad and about 40 km long. Sælsøen is one of the largest lakes in Greenland. Both lie concealed in deep longitudinal valleys, of the nature of crevasses, with steep banks on both sides, which valleys, both of them have made foundations for considerable glaciers, coming from the inland ice.

The name of Sælsøen originates from the circumstance that on one occasion we thought we saw a seal in the lake. This was however a mistake.

The surface of the lake is only 4 to 5 m above the level of the sea. The water level varies somewhat, in that during summer time it may rise, presumably about one metre or possibly more, in consequence of the melting of the snow. When travelling on the lake in the spring, one encounters along the banks, up on the land, fragments of ice, which have drifted up there during the higher water level of the preceding summer. When in the beginning of August 1912 I visited Sælsøen, the water level was about one metre higher than in May—June 1908. The rise of the water level must contribute materially to breaking the ice away from the land and so also to dissolving it. It is a likely supposition that, as a general rule, the lake becomes ice-free every year; in the unfavorable summer of 1907, however, the ice did not vanish entirely.

In May 1908 Trolle took a depth of water of 116 m in the centre of Sælsøen[1]). On the same occasion it turned out that the water at a depth of 60 m became salt, almost like the water in Dove Bugt, though with a somewhat smaller degree of salinity. Trolle is of opinion that this salt water cannot date from the time, when Sæl-

[1]) Hydrographical Observations etc., p. 337.

søen was one of the fjord arms of Dove Bugt, but that about fifty years ago it must have flooded Hvalsletten, during an exceptionally high water-level in Dove-Bugt[1]). In this connection I shall call attention to the fact that Sælsøen is a marginal lake in which the inland ice calves. In spite of the above-mentioned terminal moraine which forms a barrier over a greater part of the western end of the lake, the water depth above the part of the moraine, which lies below the water, is however quite sufficient to permit the icebergs, which are it is true quite small, to float away and drift towards east. It is certain that the bottom of the lake, also in this place, lies considerably below the level of the sea, and it is consequently not ex-

Fig. 139. View across Sælsøen. Germania Land. April.

cluded that the lake may at times be connected with Jøkelbugten below Koefoed-Hansens Bræ, or with the ice fjord of Storstrømmen (Borgfjorden) below Storströmmen. (The water of the marginal lakes in the moraine district northwest of Anneksøen, the altitude of which, above the level of the sea, is zero, was judging by a somewhat uncertain estimate from the taste faintly saline, and thus presumably was connected with Jøkelbugten, from which the lakes are separated by a distance of about 45 km.)

In the fact that the water at the bottom of Sælsøen had a temperature of + 2.36 Trolle finds a support for his hypothesis, seeing that the water would here become heated by overflooding Hvalsletten. It is however hardly necessary to have recourse to a possibility of this kind in order to explain the presence of the warm water in Sælsøen.

[1]) Hydrographical Observations etc., pp. 384—88.

Fig. 140. From Sælsøen. Germania Land. April.

Sælsøen ought presumably to be looked upon as a fjord arm, the connection of which with the sea is at present blocked by the inland ice. If the latter recedes a few kilometres, the lake will probably cease to have the character of a lake, and the level of the sea would drop to the altitude of zero. After that the outlet of Sælsøen into Dove Bugt, the Lakseelven (the salmon river), will be played out.

This river, the length of which is only 7 km, is presumably the river with the greatest quantity of water in Germania Land. Its width is 60 m, the depth at its mouth is 3—5 m; at the outlet from Sælsøen

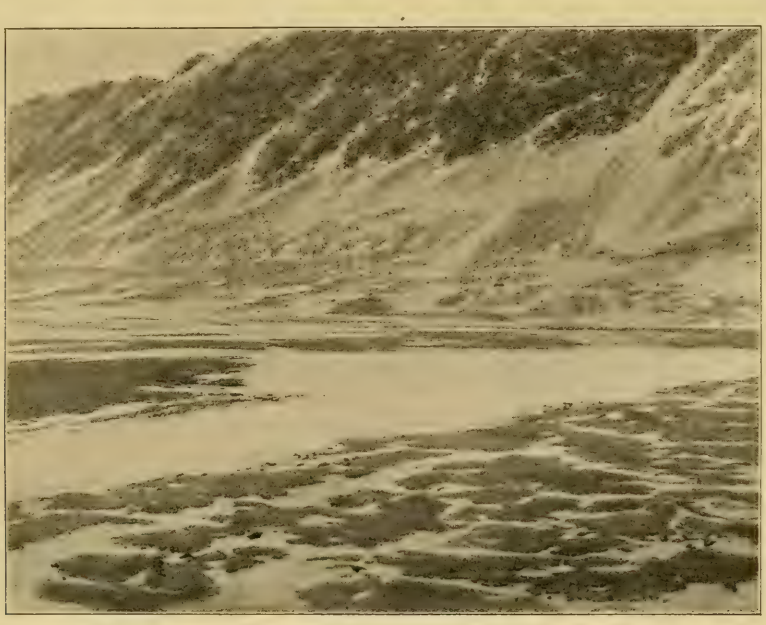

Fig. 141. Clay plain at the southeastern end of Annekssøen. Germania Land. April.

the water is presumably considerably shallower, and yet in 1912 we looked, in this place, in vain for a crossing for our horses.

The river is rich in salmon.

The surface of Annekssøen lies 40 m above the level of the sea. The level of the water varies as in Sælsøen, and during the melting of the snow may rise one to two metres. In the centre of the lake Trolle has measured the depth at 90 m. The south-eastern end of the lake, which is bounded by a terminal moraine, stretching almost from one bank to another, has a very shallow water depth and a clayey bottom; the bottom of the valley immediately south-east of the lake consists of a clay plain. The glacier, which in its time filled up the valley of Annekssøen, has in other words for a period remained stationary with the glacier front near the present

terminal moraine. In front of the glacier there was at that time a small lake, comprising the present south-east part of Annekssøen, as well as the above-mentioned clay plain. In this lake the glacier river deposited, in earlier times, the greater part of its mud, and after that continued in a south-easterly direction towards Sælsøen. This old outlet into Sælsøen is no longer in existence at normal water-level; but it is possible that it may again become active at the highest water level in Annekssøen. On the other hand Annekssøen has a rather considerable outlet towards northwest, where it disappears below Kofoed-Hansens Bræ. This water course falls in small cataracts down towards the ice margin, the foot of which, as already mentioned, lies in the same altitude as the level of the sea.

Stormelven arises from five not quite insignificant water courses, of which one or two come from the névés southwest of Kap Marie Valdemar, whereas the others rise in the boggy lowlands northeast of Moskusoksefjældene and here flow through a series of small lakes. At the lower end of its course Stormelven is 50 to 250 m broad and has a strong current. The quantity of water is considerable; still, at the end of July 1912, we succeeded though with difficulty in finding a crossing at the mouth of the river, which could be forded with horses.

Mørkefjordselven. The map of the Danmark-Ekspedition is here incomplete. The river owes its origin to two or three glacier rivers, which through large glacier gates flow out from the inland ice, and empty themselves into a large marginal lake. The outlet from the marginal lake contains nearly the same quantity of water as Stormelven. When we passed it, in the middle of August 1912, it was easy enough to ford, but the banks bore distinct traces of the fact that the level of the water, quite a short time previously, had been 1 to $1^1/_2$ m higher. In its lower course the river excavates through a gravel terrace a ravine of a depth of about 20 m. The interior of Mørkefjord is quite filled up with clay and gravel banks, originating from the river.

Further must be mentioned a marginal river in the land to the south of Hellefjord (Daniel Bruuns Land). The river was only discovered in 1912, and so is not to be found on the map of the Danmark-Ekspedition. West of Hellefjord there is on the map an indication of a "snout" in the ice margin. This is the last remains of a glacier, which once flowed into Hellefjord. In this place a glacier river debouches. Formerly when the inland ice lay only 30 m higher up the side of the mountain, the river flowed towards east down to Hellefjord through a depression, at the bottom of which there are now a series of small lakes. Now this river deflects to the south

along the margin of the ice, flows through a series of marginal lakes, finally cuts through part of Storstrømmen, and debouches into the ice fjord of the latter (Borgfjorden).

The quantity of water is considerable. Still, at the end of August 1912, we had some difficulty in finding a crossing for our horses.

The marginal lakes in Dronning Louises Land. Whereever we have reached as far as Dronning Louises Land, we have come across considerable marginal lakes or unmistakable traces of such. The marginal lakes at Ymers Nunatak, situated at an altitude of about 700 m above the level of the sea, have been exhaustively treated in "Die glaciol. Beob. d. Danmark-Expd.", pp. 34—38 of the present volume. In March 1908 an immense marginal lake was found at Kap Bellevue, at an altitude of about 300 m; it then covered an area of 30 to 50 square kilometres (see Fig. 25 in "Die glaciol. Beob. d. Danmark-Exp." and map in 1 : 500000, Pl. III). During the winter 1912—13 we discovered, at the eastern edge of Dronning Louises Land, on about 76°40′ a marginal lake of 10 to 15 km in length, and only 30 metres above the level of the sea; also in the middle and western part of Dronning Louises Land did we meet marginal lakes, respectively of about 600 and 1200 m above the sea.

It probably holds good of all of these marginal lakes that their water level varies greatly. The lakes are filled with inrushing melting water, up to the lowest pass altitude in the terrain surrounding them. In many cases the lowest pass altitude lies in the very marginal cleft, which the drainage is then made to follow as far as the next marginal lake, or until it makes its way in under the ice; but now and then one also sees the drainage of the lakes taking place out across the inland ice. This is for instance the case with Jættebringen (the giants' chest) on Ymers Nunatak and at the above-mentioned marginal lake on about 76°40′. Early or later — possibly at very long intervals — the marginal lakes further make an outlet for themselves from the bottom of the sea, in under the inland ice, and they may then become totally emptied, in so far as their bottom lies above the level of the sea. At Ymers Nunatak an emptying of this kind took place in the summer of 1907, in which manner the surface of the water had fallen about 50 m. The large marginal lake on about 76°40′ had, during the winter of 1912—13, by no means the extent which it had at a former higher water lewel, which was demonstrated by distinct terrace-formations. The outlet of the lake across the ice to the ice-fjord of Storstrømmen (Borgfjorden) consisted of an immense river bed, 15—20 m deep and 50—80 m wide. In 1912—13 this river bed was inactive, at which time the surface of the lake lay considerably lower than the bottom of the river bed.

We have seen that the more important rivers in Germania Land are glacier rivers; it is as a matter of fact owing to this very circumstance that in spite of their short length they can transport considerable quantities of water. Besides the above-mentioned there are still two glacier rivers, the waters of which however only appear in the day, after they have reached the sea. One of these has its course below Kofoed-Hansens Bræ; the other is formed from the glacier rivers of Storstrømmen and Bistrups Bræ, and debouches into the icefjord of Storstrømmen (Borgfjorden). The existence of the former has, however, not been proved; I only conclude that it must be there on account of the somewhat striking circumstance that open water forms in the south-western corner of Jøkelbugten (see map 1 : 1000000, southern sheet, Pl. V). The latter is well known. It carries such great quantities of water, that its tributaries under the ice must be supposed to stretch as far as the central part of Greenland. These enormous quantities of water flow from the icefjord of Storstrømmen (Borgfjorden), out through the many sounds in the western part of Dove Bugt. The great mass of the river water presumably passes, like the icebergs, between Edvards Ø and Carl Hegers Ø, but in this place there has been no opportunity to observe the current conditions. On the other hand, the sounds between Edvards Ø and the country south of Hellefjord (Daniel Bruuns Land) were in 1912 several times navigated by myself with a motor boat, and every time under the greatest difficulties owing to the current conditions. In the narrow sounds the current, in great whirlpools, crushes outwards with a speed varying with the tidal wave, and which we estimated at 3 to 6 knots. The clayey waters of the glacier river could be followed as a broad brownish ribbon in Dove Bugt, as far as Spydodden (the spear point) and probably still further.

Beyond the above description from Germania Land and Dronning Louises Land we know no more of lakes and water courses in Northeast Greenland, than what has been indicated in the maps i. e. practically nothing. It must here be borne in mind that the investigation of the tracts lying north of Germania Land was undertaken on a forced sledge trip in the spring. The conditions on a hard sledge trip as a rule do not permit one to make longer excursions across the country, and besides in the spring the river beds are dry and the smaller lakes hidden under the snow.

In particular in Peary Land it must be supposed that it will be possible to come across larger lakes and more considerable water courses, such as for instance Knud Rasmussen and Peter Freuchen came across in Valmuedalen, during the summer of 1912. Hagen who together with Mylius-Erichsen and Brønlund spent the summer of

1907 at Danmarksfjord, has in his map plotted a couple of fairly large lakes and a great number of water courses of which at any rate one — in the interior of the Danmarksfjord — judging by the map must be supposed to carry a considerable quantity of water. KNUD RASMUSSEN and PETER FREUCHEN, who in the early part of the summer of 1912 from the inland ice descended into Danmarksfjord, in Zig-Zag-Dalen (the zig-zag valley, discovered by KNUD RASMUSSEN and so not included in the map of the Danmark-Ekspedition) came across a whole series of small lakes.

The lakes and water courses, which KNUD RASMUSSEN and PETER FREUCHEN discovered west of Independence Fjord, and among which in particular Nyeboes Randsø (N.'s marginal lake) is of no small interest, lie outside the stretches covered by the Danmark-Ekspedition, and thus will not be mentioned in this place.

The Climate.

The meteorological observations are exhaustively treated in Medd. om Grønl. XLII, by WEGENER in "Meteorologische Terminbeobachtungen am Danmarks Havn" and "Drachen- und Fesselballonaufstiege", by BRAND and WEGENER in "Meteorologische Beobachtungen der Station Pustervig" and by BRAND in "Die Temperatur in der Ausguckstonne". From the discussion of the meteorological phenomena further appear the single features of the climate of the country, but as a matter of fact scattered and disconnected. I have, therefore, thought it best in this place to give a concise description of the climate, founded on WEGENER'S and BRAND'S treatment of the meteorological material of the Danmark-Ekspedition, augmented by a few observations made on later occasions.

The climate is, even at the outer coast, a continental one. This appears from all the climatological factors, but most distinctly perhaps from the temperature, in that the yearly amplitude — computed from the mean temperature of the months — is about 32°. The cause of this state of affairs is to be looked for in the East Greenland current, which is practically covered with ice during the greater part of the year and so, climatologically speaking, must be regarded as forming part of the land. The ice conditions of the sea, varying from one year to another, quite naturally entail corresponding changes in the climate. It then follows, as a matter of course, that a representation of the climate which, like the one we are dealing with, is mainly based upon meteorological observations undertaken during a period of only two years, must be put forward with a certain reservation.

A comparison with the results of the Germaniaexpedition suggests that the continental character of the climate becomes more pronounced towards the north, which circumstance is to be explained through the ice conditions of the coast sea. Further, a comparison with the observations from the two stations, Pustervig (Nov. 1907—May 1908) and Borg[1]) (Oct. 1912—April 1913) situated about 60 and 100 km west of Danmarks Havn, shows the quite natural state of affairs that the continental character of the climate, also towards west, becomes more pronounced.

The yearly mean temperature is, as far as Danmarks Havn is concerned, $\div 12°$ to $\div 13°$ (Centigrade), but already at the margin of the inland ice, about 100 km further west, we encounter winter temperatures which are about 10° lower than at the coast, and a yearly mean temperature which may be estimated at $\div 16°$ to $\div 18°$ (Station Borg 1912/13). Only during the three summer months do we find positive mean temperatures (in the case of Danmarks Havn: June $+ 1°.1$, July $+ 4°.4$, August $+ 2°.2$); all the other months have negative mean temperatures, which in the winter fall to $\div 25°$ to $\div 35°$. The highest temperature measured at Danmarks Havn was $+ 17°.1$ (July 7th 1908); the lowest was $\div 40°.9$ (March 11th 1907). The lowest temperature measured at Borg was about $\div 50°$.

The chief direction of the wind is round northwest; furthermore, the winds between west and north are the only ones which blow with considerable force. The meteorological journals of the Danmark-Ekspedition show that for more than half the time we have had winds between west and north, and that for nearly a fourth of the time we have had calms; for the remainder of the time, in other words not even a fourth of the time, we had wind directions between northeast, east, southeast, southwest.

The northwesterly winds increase both in force and frequency the higher one gets: from an altitude of 1000 m and upwards they prevail almost entirely. These northwesterly land winds are dry and comparatively warm; they blow irregularly, in gusts, and may sometimes assume the character of føhn winds.

The easterly winds are, in the main, not frequent, yet for the months of May, June and July they cover more than a fourth of the time. These winds, blowing from the sea, are moist. They blow evenly and with little force, on an average perhaps 3 to 4 m per second, and rarely more than 6 m per second. The velocity decreases in an upward direction; as a rule the easterly wind does not reach higher than 300 m. When these winds, saturated with moisture,

[1]) The observations from Borg have not been published. They will appear later on in Medd. om Grønl.

strike against the coast land, which particularly in May and June is relatively very cold, the moisture condenses into fog. This fog is therefore, particularly in the early summer, characteristic of the outer coast. It was this fog which in 1900 forced PEARY to stop at 82°57′, when towards the end of May he attempted to travel south along the east coast of Peary Land. It was likewise this fog which during the latter half of May and June 1907 so greatly hindered the sledge travellers of the Danmark-Ekspedition on the whole stretch from Kap Bridgman to Danmarks Havn. The easterly winds often lack the force to penetrate far across the land; consequently one often sees that the fog only lies above the outermost coast land and at the mouths of the fjords; and even in the rarer cases, where the fog has sufficient strength to reach as far as the margin of the inland ice, does one as a rule see the great areas of plateaus and mountain ranges projecting through the fog.

Thus the easterly winds are, particularly during the early summer, a rather important factor in the climate of the outer coast; but according as we move away from the outermost coast line or ascend the mountains, the importance diminishes, and at the margin of the inland ice or at an altitude of 300 m the easterly winds and the accompanying fog are practically played out, which circumstance, as we shall see below, leaves its traces on nature.

The extent to which the westerly winds prevail, when from the margin of the inland ice one goes farther west, in across Dronning Louises Land and the inland ice, was borne in upon us during the voyage across Greenland in 1913. On April 20th we left Borg (about 22°30′ west of Grw.; on May 31st we had practically reached the centre of Greenland (about 38° west of Grw.). During these forty days we had had no easterly winds at all, and only two days of moderate winds or calm. During the remaining thirty-eight days we had had a stiff westerly breeze, which for twelve days forced us to lie over.

With the exception of the three summer months, the wind, when it has a velocity of more than 5 to 6 m, nearly always causes the snow to drift. The drifting of quite fine and loose snow has, it is true, been observed under smaller velocities of the wind; but the carriage of snow, caused in this manner, is of no practical importance. At a velocity of 6 to 7 m the drifting on more even planes, for instance on the fjords, assumes quite a regular character without, however, rising more than a few decimetres above the ground. In these cases the drift of the snow is not evenly distributed, but lies in winding streaks, which are driven before the wind, not unlike a thin white smoke. These streaks occur as a natural consequence of

the circumstance that the wind at the points, where once it has taken hold, will more easily eat further into the cover of snow and fashion it into the well-known sastrugi. At a velocity of 10 to 15 m the drifting snow already fills the air up to an altitude of several metres, and at 20 m the snow is whirled up to an altitude of 15 to 20 m.

In a mountainous terrain the regularity of the drift is naturally lost, and there the air, in particular in the shelter of the mountain ranges, may be filled with drifting snow, up to an altitude of several hundred metres.

Cyclonic storms only occur in the autumn and winter. The velocity of the wind is not very considerable, and only in exceptional cases does it seem to reach 30 m, but nevertheless they make an almost overwhelming impression, on account of the great quantities of whirling, stinging snow which fills the air. For the traveller in a snow storm the strong impression, however, speedily becomes less, on account of the continued and exhausting struggle against the wind and particularly the snow, which closes up the eyes and in the long run has a stunning, stupefying effect upon the senses. Travelling against a snow storm is impossible; on the other hand it is quite possible to travel with the storm at one's back, when one can otherwise find the way. For sledge travellers snow storms generally involve no danger, because one may at any time stop and — though with some difficulty — pitch one's tent. On the other hand there are many examples of people, who having ventured out alone into snow storms, though only for a few hundred metres, have been unable to find their way back.

The føhn wind, which during the whole year may assume a stormlike character, alone causes the few storms of the summer.

The precipitation at Danmarks Havn was measured at 146 mm, of which four-fifths fell during the six winter months. By far the greater part of the precipitation was in the form of snow, whereas the rainfall did not quite amount to 10 %. This summer rain often assumes the character of a quite transitory drizzle, which immediately evaporates on the soil heated by the sun; however, it would appear as if conditions in this respect, as well as in others, may vary greatly from one year to another. During the summer of 1912 we several times had a steady rain, heavy enough to penetrate our clothing. Also Knud Rasmussen's and Peter Freuchen's descriptions of the weather conditions in 1912 in Vildtland and Valmuedalen (about 82° N. Lat.) suggests a very rainy summer.

Even though it may be supposed that the result arrived at by the Danmark-Ekspedition, as regards the summer rain, does not

correspond with "normal" conditions, it is, however, quite certain that it is only a small portion of the precipitation which falls in the form of rain. This is of no small importance, because large portions of the snow do not, like the rain, distribute themselves evenly over the land, but when the drifting takes place collect in larger and smaller drifts in certain localities sheltered from the northwesterly winds, whereas the stretches particularly exposed to the wind are

Fig. 142. Föhn clouds. August.

almost cleared of the winter snowfall, when the melting of the snow begins.

The quantity of clouds above Danmarks Havn is largest in January, smallest in April. Upon the whole it is greater in the winter months and in June and July than during the remainder of the year. As far as the winter months are concerned, the greater quantity of clouds, in a very material degree, originates from the snowstorms, in other words from a circumstance not peculiar to the outer coast (Danmarks Havn). As far as June and July are concerned, the greater quantity of clouds originates from fog and, as mentioned above, we do not find this to the same extent at a greater distance from the coast.

The forms of clouds are of less interest as a climatological factor. Considering the importance of the matter from the point of

view of the landscape, I take occasion to draw attention to the fact that the cumulus clouds, so common elsewhere, are almost entirely unknown in Northeast Greenland. In return a kind of cloud, which Wegener has called the føhn cloud, occurs so frequently that partly by reason of its peculiar form — it leaves its special impress on the sky of the coast land (see the illustration material in Meteorol. Terminbeob. am Danmarks Havn, Medd. om Grønl, XLII, pp. 308—309).

The manner in which day and night alternate within the Arctic circle appears with particular clearness in North Greenland, on account of the high, northerly position of this country. The proportion is shown in the table below:

Locality	Latit.	Approximate duration of the winter night		Approximate duration of the summer day	
		from—to	days	from—to	days
Dove Bugt	76°30′	12/X—3/III	about 104	25/IV—19/VIII	about 117
North point of Greenland.	83°30′	1/XI—12/II	— 144	6/IV—8/IX	— 156

Under climatic conditions like the ones just now described it may seem peculiar that organic life, and in the circumstances rather a prolific one, can thrive in these localities. For the vegetation and for certain lower animals which, by reason of the cold, must in any case pass the winter in a lifeless dormant state, it does not play any real part, whether they are cooled off to $\div 10°$ or to $\div 40°$; life is extinct in them, and it is therefore scarcely reasonable to suppose that the winter darkness plays any part, as far as these organisms are concerned. On the other hand, the winter storms and the drifting of the snow become of importance, particularly in the case of plants.

On the slopes and hilly tracts most exposed to the wind the storms and the drifting of the snow throughout the winter exert a purely mechanical wear and tear. And further, as the snow cannot remain on the ground, the moisture conveyed to these places during the summer is a minimum. Quite apart from the conditions of the soil localities of this kind therefore belong to the most barren stretches.

In the lee of slopes facing east, southeast and south snow may accumulate in very large drifts, so large in fact that they become perennial, and in the autumn, when the melting of the snow ceases, leave a residuum of an ice-like character. That the larger snow-drifts, which can hardly melt away in the course of one summer, form a serious obstacle to the local vegetation is self-evident; but

also smaller drifts, with a thickness of only a few metres, exert a hampering effect.

Any real protection against the cold is not offered even by the largest snow drifts. The temperature of the surface of the earth below the snow drifts must in the course of the winter, in consequence of the cold penetrating both from above and below, towards the surface of the earth, drop at least to the mean temperature of the year — in the case of Danmarks Havn ÷ 12° to ÷ 13°. On the other hand the snow drifts in the spring and early summer constitute an almost complete obstacle to the solar radiation. The soil below the snow-covered areas cannot begin to thaw, before the snow has almost entirely melted away, and so only at the last stage of the melting process does it become able to absorb the moisture conveyed to it by the melting snow. The areas which only become devoid of snow at a late period get too short a summer; vegetation does not get the requisite time for its development.

The snow drifts are the depots of the snowfall; their effect is similar to that of fountain heads. In order that the melting water may be fully exploited for the benefit of vegetation, particularly favourable terrain conditions are required, which may cause snow-bare land to become irrigated; in other words, below the drifts or their drains there must be even planes with a very slight declivity; in such planes bogs form, and these are, with a few exceptions, the only places where we may find something approaching to a large continuous carpet of vegetation. On stretches of this kind the drifting snow distributes itself fairly evenly, in a similar manner as it does on the fjord ice, and with a layer the dimensions of which, roughly calculated, vary between a thickness of $^1/_4$ to $^1/_2$ metre. The first falling snow is held fast by the vegetation, and therefore protects the latter against the mechanical wear and tear of the drifting snow.

Fortunately the arctic nature has, as mentioned above, in the moutonnéed landform a pronounced tendency towards forming these almost horizontal planes, because the upper layer of earth, thawed and saturated with water, slides rather easily on the frozen bottom, which lies deeper. Small boggy tracts are therefore a rather common occurrence in the lowland (Basiskæret, Vesterdalen, the valley east of Varderyggen, the middle course of Stormelven, Ryleskæret west of the mouth of Stormelven), and according as one goes in a westerly direction towards the inland ice, the boggy tracts gradually increase in frequency and size.

This can scarcely be ascribed to chance, but it is to a certain extent connected with the fact that the climate towards west assumes a more pronouncedly continental character.

Besides the meteorological temperature the solar radiation plays an extremely great part in the life of plants. Among others Lundager has demonstrated this on the Danmark-Ekspedition by undertaking a series of temperature measurements with a black bulb thermometer[1]). As soon as the snow has disappeared, the soil is strongly heated by the solar radiation, and in this manner heat is again conveyed to the lower strata of the air. As we have seen, it is however in the very months of May and June that the fog settles over the outer coast and prevents the continued solar radiation. The importance of this appears among other things from the fact that the rivers at the eastern part of Ymers Nunatak — about 55 km towards the interior of the inland ice and at an altitude of about 800 m above the level of the sea, the mean temperature of which locality may be estimated at about $\div 20°$ — in 1908 broke up in the middle of May, whereas at Danmarks Havn they only did so a month later. It may therefore justifiably be presumed that the spring and summer manifest themselves at an earlier period, as well as more strongly, at the margin of the inland ice than at the outer coast.

The fog conveys moisture to the soil or at least checks the evaporation, and the summer must consequently become drier, the less fog there is. In 1912 it also seemed to me that the mountainous tracts in the land south of Hellefjord (Daniel Bruuns Land) has a still sparser vegetation than the mountain stretches near the outer coast. But the increasing dryness of the climate plays no part, as far as the bogs are concerned, seeing that the drifts of snow can supply sufficient water for the irrigation of the latter. On the west side of Daniel Bruuns Land, in other words right up to the inland ice, there are many and comparatively large boggy tracts, the largest of which is, roughly speaking, about 30 square kilometres.

To the Danmark-Ekspedition the existence of this comparatively luxurious boggy vegetation in Daniel Bruuns Land was unknown. Nor did we consequently know at the time that in this very place there were larger quantities of musk oxen and hares, and perhaps also of foxes, than in any other part of Germania Land.

In this connection I shall mention an observation, which possibly has to do with the peculiarity that the sea fog only in exceptional cases reaches higher than 300 m, that is, the presence (end of July 1912) of large swarms of mosquitoes in the Moskusoksefjeldene, which made a night we were compelled to spend in one of the mountain

[1]) Andr. Lundager: Some notes concerning the vegetation of Germania Land, Medd. om Grønl. XLIII, pp. 372—381.

passes almost unbearable. In the highest parts of Moskusoksefjeldene there are a large number of small valleys with water holes and a sporadically occurring boggy vegetation, so that the conditions in this very place are presumably favourable to the development of the mosquito larvæ. It must be borne in mind that in 1912 we did not come across mosquitoes in unpleasant numbers, neither at Danmarks Havn nor elsewhere on the low land. Nor did we in 1906—1908, as far as I know, come across such numbers of mosquitoes that we found it necessary to use mosquito nets or to take other measures for our protection. When we arrived at Daniel Bruuns Land in 1912, the season was too far advanced (end of August) to make it likely that we should come across mosquitoes in large numbers.

Mirages.

In the atmosphere of the Polar regions a number of optical phenomena occur — aurora polaris, halo phenomena, mirages — which even though they are not particularly restricted to the polar zones, yet contribute towards giving arctic and antarctic Nature its peculiar stamp. In this place I shall only mention the mirages, such as they appear most commonly in Northeast Greenland.

In the course of the later expedition 1912—13 the mirages were subjected to a systematic investigation. This will be made the basis of a more elaborate treatment of the subject to appear later on. In this place I will only give a representation of the elementary optical principle, in order to enable the reader to understand the nature of reflection without having recourse to the technical literature [1]).

The condition for mirage taking place is that the density of the air does not decrease evenly in an upward direction, but in jumps, so that one may speak of a bounding surface between two air strata. At this bounding surface a total reflection may then occur, and in that manner we get a mirage. According as the denser medium lies uppermost or nethermost, the "downward mirage" or the "upward mirage" occurs.

The rays of light are not suddenly refracted in the same manner as in a prism, but are subject to a gradual deflection; for the sake of simplicity I have in the figures below represented it as being a reflection in the true sense of the word. Further I have, for the sake of distinctness, drawn the rays of light much steeper than they are in reality. The deflection to which the rays of light are subject

[1]) J. M. Pernter: Meteorologische Optik, Wien und Leipzig 1902—1910 has in chapters 3 and 4 "Luftspiegelungen und Fata Morgana und verwandten Erscheinungen" given a detailed description of the phenomena appertaining to this subject.

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only comes to a few minutes. In other words, mirages in Nature are almost always seen in a direction, which does not deviate very much from the horizontal one; only in those rare cases where the surfaces between the strata of air are not very nearly horizontal, can one see mirages in directions deviating considerably from the horizontal direction.

The downward mirage is in particular connected with the first thin ice cover of the autumn, but is by the way also to be seen in the summer and spring. When the temperature in September—October falls to $\div 10°$ to $\div 20°$ in calm weather, immediately above the thin ice heated by the water, a stratum of warm air forms, which for a time may stand rather sharply against the cold air higher up. In the transition between the two strata of the air, the rays of light are broken or deflected and produce the downward mirage in the case of an observer, who finds himself just above the boundary between the strata of air and thus in the denser medium.

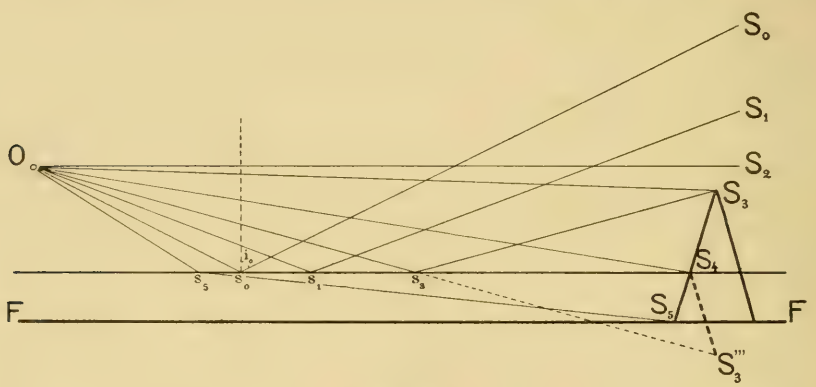


Fig. 143.

In Fig. 143 *FF* indicates the surface of the sea, whereas the line $s_5 s_0 s_1 s_3 S_4$ indicates the bounding surface between the two air strata. The angular limit for the total reflection be i_0. The observer finds himself in O; his horizon lies in the direction OS_2.

The ray of light $S_0 s_0$ is totally reflected to O; in the direction Os_0 is thus visible a reflected image of a point of the celestial vault.

Similar conditions hold good as regards the ray of light $S_1 s_1$. The reflected image and the directly seen image come into contact in the direction OS_2. As these two images are entirely alike and lacking details, the boundary line between them is wiped out i. e. the real horizon which lies in the direction OS_2 is not visible, but instead of that a false horizon has appeared in the direction Os_0; in other words, the horizon is apparently lowered the angle $S_2 Os_0$.

On the stretch from s_0 and in an outward direction thus only directly appear the objects projecting above the bounding surface between the strata of air. This is the case with the rocky holm $S_5S_4S_3F$ shown in the figure; the latter is directly visible in the angle S_3OS_4 and reflected in the angle S_4OS_3'''. The part of the rocky holm situated below the bounding surface between the strata of air ought theoretically to be directly visible, but separated from the remaining part, in the angle s_0Os_5. However, I do not know whether we have ever seen this part of the image, the reason presumably being that the bounding surface between the strata of air often only lies 1 to 2 metres above the level of the sea. The section S_4S_5 thus becomes so small that it can only appear as a line, which it is difficult to discern, and which therefore in the case in point coincides with the false horizon, whereas in other conditions it may lose itself in the reflected image of the upper part of the mountain.

Fig. 144. Downward mirage of the "Skerry". October. [From Alfred Wegener: "Terminbeobachtungen am Danmarks Havn", Medd. om Grønl. XLII].

We may now leave the optics and return to geography.

The immediate impression which the observer receives of the optical phenomena is that — corresponding to the direction Os_0 — there is a bounding line, where a change occurs in the landscape, but the manner in which the change is regarded varies according to the character of the surroundings, and in particular of the background. With a practically free horizon, which in ordinary circumstances is only broken by single icebergs or holms, the case becomes as mentioned above. The reflected image of the celestial vault then comes into contact with the directly seen celestial vault; the two images coalesce; the real horizon disappears, and a rather sharp and extremely deceptive false horizon may appear, lying considerably lower than that which has disappeared. The holms and icebergs are seen floating freely in the air above the false horizon, perhaps a trifle fuller in shape than one is accustomed to see them, but otherwise to a casual observer with their usual contours. Only on closer inspection does one discover that their images are displayed fairly symmetrically on both sides of a horizontal axis corresponding to the bounding surface between the two strata of air. Just because the attention is first and foremost attracted by the directly visible part of the holms and icebergs, which stand out calmly and rather sharply with their usual upper contours, it makes an all the more startling effect to see them floating up in the air.

If on the other hand one looks across a closed fjord, where the

field of vision is, at the background, bounded by mountains, the reflected image of the celestial vault gives the impression of being open, crystal water, in which the icebergs, holms and mountains are reflected. This "open water" has a doubly deceptive effect, because in the autumn one must be prepared to find the current ripples open; as a rule one only realises that one has been the victim of an optical illusion, when approaching the imaginary opening, cautiously testing the strength of the ice. If one's attention is particularly directed towards the phenomena, one will however generally be able to recognize the mirage by a trifling movement in the reflected images or in the contours of the openings.

The upward mirage is conditioned by the denser medium — the cold stratum of air — being the nethermost one. The phenomenon is of rather a common occurrence in all seasons, but it occurs particularly often in spring on the sea ice, where it is, so to speak, to be seen any sunny day. Just as the temperature of the ice in the autumn cannot follow the rapid cooling off of the air, but lags behind, in the same manner it cannot keep up with the heating in the spring. The stratum of air nearest above the ice is consequently cooled off, when coming into contact with the colder ice, and in calm weather a stratum of cold air may form which is sufficiently sharply defined to bring about a total reflection.

The common objects of the reflection under these conditions are the coast and the pack ice. The coast gives the impression of being finished off with a terrace falling off vertically towards the sea, which seems to be built of vertical columns. The details of this column structure are not easily got hold of, because they change so quickly, and because the mirage is often enveloped in a glimmering haze, which circumstances are connected with an extremely rapid change of temperature in the boundary between the strata of air. As an example see the thermogram for March 9—16 1908, Medd. om Grønl. XLII, Pl. XVIII, p. 318. In reality the elementary fluctuations take place much more rapidly than the thermogram shows; the instrument is not sufficiently sensitive to be able to follow the rapid variations of the temperature. This boundary, in other words, consists of an undulating plane, which must give a changing, blurred and streaky effect to the reflected images (compare the moon bridge, the reflection of street lamps in water and similar things). The pack ice when reflected appears as a rather sharply defined ice wall with a column structure. It is rather a common occurrence to see two ice walls, the one above the other, showing a reflection against two different bounding surfaces. (As the Danmark-Ekspedition had no photos of mirages of pack ice, I have in this place reproduced

Fig. 145. Downward mirage in Dove Bugt. October 1st. The dark plane in the foreground is new ice.
[From Alfred Wegener: »Terminbeobachtungen am Danmarks Havn«. Medd. om Grønl. XLII.]

Fig. 146. Downward mirage of Kap Bismarck and the little island Maroussia. October 1st.
[From Alfred Wegener: »Terminbeobachtungen am Danmarks Havn«. Medd. om Grønl. XLII.]

Fig. 147. Upward mirage (»Verticalverzerrung«) on the coast of Lille Koldewey. February.
[From Alfred Wegener: »Terminbeobachtungen am Danmarks Havn«, Medd. om Grønl XLII.]

Fig. 148. Upward mirage in the marginal zone of the inland ice. In the background Dronning Louises Land. March 1913.

a photo from 1913 of the quite analogous phenomenon from the marginal zone of the inland ice).

In Meteorol. Terminbeob. am Danmarks Havn, Medd. om Grønl. XLII, WEGENER has published a great number of sketches and some photos of mirages. By going through the latter one will quickly find a series of upward mirages, which do not accord with the above description (see for instance the sketches on pp. 241, 288, 292, Plates XI and XII and others). The inversion of temperature conditioning these mirages at Danmarks Havn lies at an altitude of 500 to 600 m. In Drachen- und Fesselballonaufstiege, Medd. om Grønl. XLII, pp. 62—64 WEGENER quite briefly mentions the meteorological conditions pertaining to this kind of upward mirages. In particular I shall draw attention to the curves of temperature delineated on p. 65, which show that the rise in temperature may take place in a series of small jumps, corresponding to the same number of bounding surfaces, each of which may cause a reflection. These upward mirages are materially different in character from the above. The column structure is only slightly pronounced, and is perhaps lacking altogether; the reflected image is not limited to a narrow streak, but lifts itself high into the air; the boundary line at the top is, as a rule, jagged and very uneven in height; the movement in the images is quieter, which shows that the waves of the bounding surfaces in this place are of a somewhat different kind. If one finds oneself on a mountain and quite close under the reflecting surface, the images, owing to one's own movement up and down, may change both quickly and strikingly, as will appear from the description below of a reflection in Dronning Louises Land.

It is by no means an uncommon phenomenon in the autumn simultaneously to come across upward and downward mirages.

In order to give a somewhat more complete idea of the impression which mirages may produce upon the observer, I will to conclude quote the description given of two particular cases from the voyage across Greenland in 1912—13.

Borgfjorden (the ice fjord of Storstrømmen) Sept. 20th 1912.

— — — Homewards we went, with empty sledges and in our old tracks. There was time to enjoy the beautiful clear and frosty September evening. The shining, white fresh snow, wreathing the upper edge of the icebergs, enhanced their blue and yellow-red colours. The generally so massive and imperturbable ice colosses became light and airy. They stretched in a downward direction and seemed to rock gently on a crystal lake in the snow-covered plain of the fjord.

It was the downward or the "autumn" mirage in the warm

air,[1]) which formed over the thin ice sheet of the fjord. It tried to impart a little life to the dull and sluggish icebergs, but the task was too hard for it. It missed the assistance of its strong brother, the upward or the "spring" mirage. When the latter sets to work, the icebergs become frolicsome and wanton.

Borgjøkelen[2]) April 12th 1913.

— — — When we got further east, down over the Borgjøkelen, we passed the boundary between two sharply separated strata of air, and immediately the mountains round us began to be reflected.

Fig. 149. The left mock-sun and parts of the small halo and the horizontal ring projected against Stjernefjeldene. Pustervig, Germania Land. March.

It was the "spring mirage", which here imported life to quiescent nature.

And while the sledges were going up and down along the uneven, hummocky ice, the character of the images changed.

From Kap Aage Berthelsen a reflected streak projected towards Gundahls Knold. It undulated backwards and forwards, split up into two parallel parts which again joined together, all at once thrust out a quivering tongue far towards north, and then with the same suddenness withdrew it into the solid mountain side.

The mountain north of Gundahls Knold rose on tall and slender columns. Column beside column made a continuous airy wall, which upheld the natural domelike top of the mountain.

[1]) This expression is, as will be seen, not exact.

[2]) A large glacier, stretching from west to east across Dronning Louises Land.

But close to the mountain lay quite a small knoll, hardly 50 metres high, which made the most desperate efforts to inflate itself, so as to become as big as its great neighbour. It breathed deeply, took a short run, made a tremendous jump right into the air, for a second or two retained its many times doubled size, and then once more sank back into its natural insignificance.

Then it rested a while, collected itself and went at it again.

A fresh jump in a desperate hurry, and this time it reached so high that it became detached from its foundations. It was quite a summersault, which made it float high up in the air, with its top downwards and its base upwards. For a long time it remained floating, undulating, nodding to its second more solid self on the firm ground, and reaching out a long arm towards its big haughty neighbour, in order to show that they were now equals.

Then the sledge rushed for quite a long distance down a slope. The large mountain trembled and half dropped on its knees. But the little knoll had to return to the place where it belonged.

And the stones on the near mountain side and the still nearer ice knolls twisted themselves about in fantastic shapes, craned their necks, raised their heads into the air and cried out to me: "You forget to look at us; we also are able to do things; we also are in the mirror dance! Now you must behold us!" — — —

CONTENTS

Page

INTRODUCTION 81
Basis of the formal treatment of the material — Cartographic object of the expedition — Inventory of instruments.

CHAPTER I
The Work in the Observatory.

The Observatory 88
Universal instrument — Watches — Thermometer and barometer — Electric light.

Determination of azimuth 101
Example of observation and computation.

Determination of time in the vertical of a polar star 103
Clock comparisons — Thread intervals — Azimuth tables — Examples of observation and computation — Abbreviated computation — Rate of the watches.

Determination of longitude by transits of the moon and an adjacent star 118
Principles of the determination — Preparations for the observation — The carrying out of the observation — Preliminary computation — Example of observation and computation — Summary of results — Mean error.

Determination of latitude 130
von STERNECK's method — Preparations for the observation — Observation and computation — Result and mean error.

Astronomical refraction in arctic regions 136
Earlier investigations by BØRGEN and COPELAND — Investigations by the Danmark-Ekspedition.

Terrestrial refraction 147
Reciprocal, simultaneous zenith distances above land and water (ice) — Relative determinations — Absolute determinations at the sea horizon — Critical remarks on the observations — Variation of the co-efficient of refraction according to the season — Variation of the co-efficient of refraction according to the time of day — co-efficient of refraction and actinometric difference — Examples of anomalies of refraction — Concluding remarks.

CHAPTER II
Base Measurement and Triangulation.

Base measurement 199

Triangulation. Surveying operations 202

Computations of the triangulation net 211
Eccentricity — Base net — Triangulation net proper — Accuracy attained — Inclusion of the observatory in the triangulation network

Levellings of the triangulation points 225

Triangulation net at Dove Bugt 230

Geographical co-ordinates of the triangulation stations 233

Position of Haystack 337

Drift of North Greenland in a westerly direction 240

CHAPTER III

The Geographical Survey.

Page

Introductory remarks. Instruments 257

Astronomical determinations 261

Refraction table — Azimuth table — Determinations of latitude — Determinations of time — Determinations of azimuth.

Determination of longitude during the sledge trips to Kap Bridgman in 1907 and to Dronning Louises Land in Maj 1908 288

Geographical sketching survey 294

Perspective sketches — Bearings and levellings — Measuring of distances, vertical base — Measuring of distances, horizontal base — Notes made during the journey — Map sketching during the voyage — Map of the single tracts.

Extract of KOCH's diary on Peary Land containing in full the cartographic material from the east coast of Peary Land 314

Geographical survey of Dove Bugt 353

Observations from Station XXIV, Teufelkap — Latitude — Azimuth — Station pointing — Computation of geographical co-ordinates — Sketching survey.

Levellings 360

Sources of errors — Principles for indicating the altitudes on the maps — Estimation of the accuracy.

Notes to the geographical maps 366

Scale — Projection — Reliability of the maps — Work of the different cartographers — Contours — Figuration of the relief — Indication of ice and water — The names.

CHAPTER IV

Head of Independence Bay 378

An investigation of Hagen's cartographic material from the interior of Independence Fjord.

CHAPTER V

The Topographic Survey.

Mode of execution 293

Notes to the maps 396

Danmarks Havn and Environs, scale 1:100000, Pl. II — Part of Winges Coast, scale 1:25000, Medd. om Grønl. XLV, Pl. VII — Karte der Gnipahöhle, scale 1:4000, Pl. I — Danmarks Vinterkvarter 1906—08, scale 1:2000, Medd. om Grønl. XLI, Pl. III — Map sketch of Pustervig.

CHAPTER VI

Features of the Geography of Northeast Greenland.

Distribution of land and water. The coast line 402

Ice foot, tidal cracks and tidal pressure ridges — Insularity of Germania Land.

The coast sea 409

Bays, fjords and sounds 412

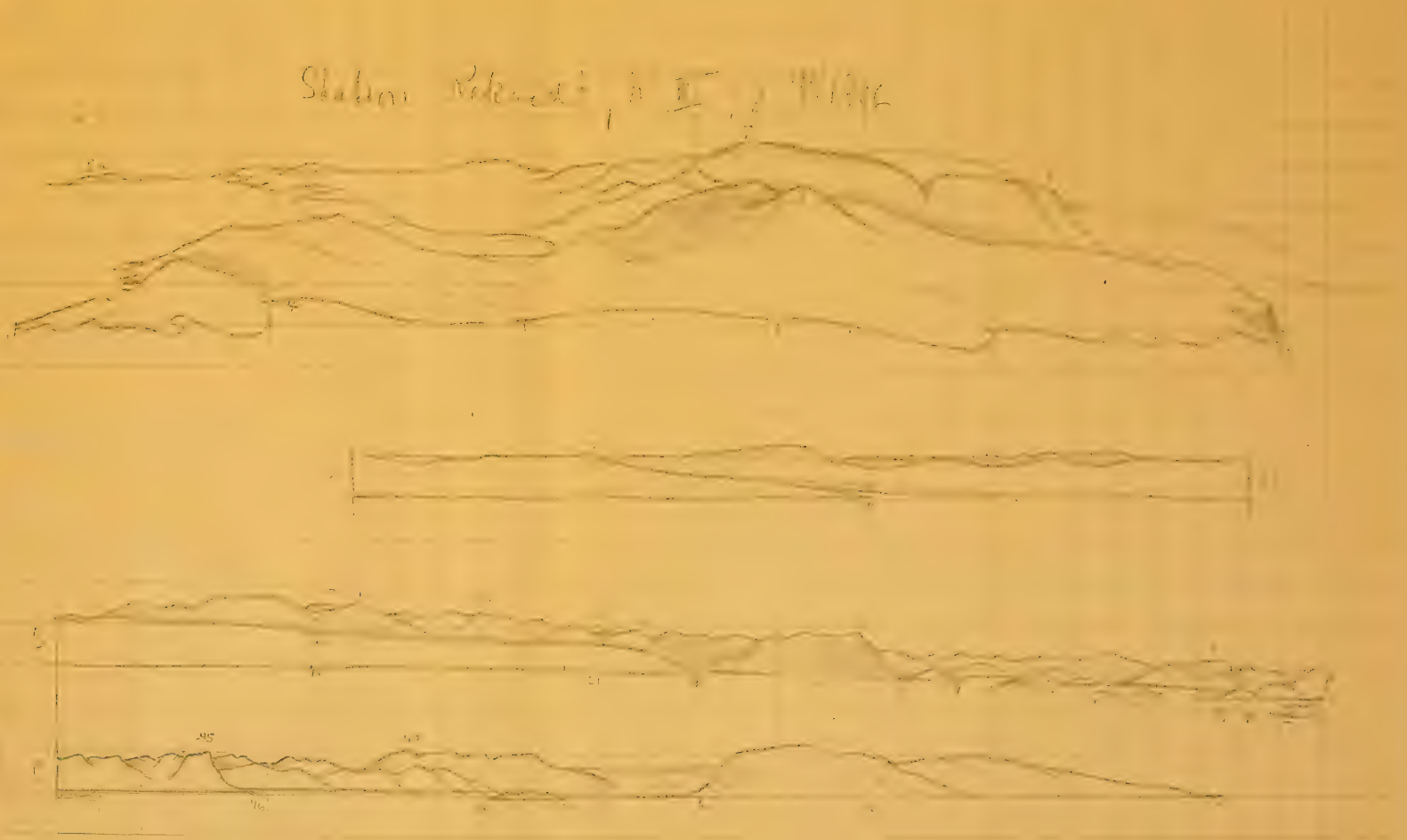
Ice conditions — The sikosak — Icebergs.

The coast land 430

Alpine landform — Ice period landforms — The moutonnéed landform — The plateau landform — Transition forms — Moraines — Hvalsletten.

Lakes and water courses 442

Climate — Mirages 451



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